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Stratigraphy of Lower Ordovician Nittany Dolomite in Central Pennsylvania

Allen R. Spelman

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Stratigraphy of Lower Ordovician Nittany Dolomite in Central Pennsylvania

by Allen R. Spelman
Geologist
Texaco Inc.

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STRATIGRAPHY OF LOWER ORDOVICIAN NITTANY DOLOMITE IN CENTRAL PENNSYLVANIA

By

Allen R. Spelman*

ABSTRACT

The Nittany Dolomite was measured and described in detail at four sections at and in the vicinity of Bellefonte, Centre County, the type locality. One of these four sections, the Bellefonte section, is believed to include exposures originally used by Ulrich (1911) for the type section. These sections were employed by the writer to establish the presence of three lithologically distinguishable sequences, a basal Forge Union Member, middle Shoenberger Member and the uppermost Etna Furnace Member. The lithologic characteristics of formations directly above and below the Nittany Dolomite at Bellefonte, as well as locations of their contacts also are discussed. Attention is given to changes in the physical and mineralogical characteristics of each member of the Nittany as observed in eight sections southwestward from Bellefonte to Lutzville in central Bedford County, and to changes in lithologic characteristics and boundaries of stratigraphically adjacent formations.

Many of the fossils collected during this study have not been previously reported from the Nittany Dolomite in central Pennsylvania. Fossils collected by the writer and by previous workers are listed, and their stratigraphic occurrence and method of preservation are indicated.

The Nittany Dolomite is composed almost entirely of the rock dolomite. The occurrence and arrangement of the morphological varieties of the various carbonate and noncarbonate minerals that comprise these dolomites, and the textural aspect of dolomites and the sedimentary structures developed in dolomites of the Nittany Formation are described. The various types of dolomites that occur in the Nittany Formation are grouped into ten dolomite lithotypes and five sublithotypes on the basis of dolomite crystal size and sedimentary structures; the characteristics and abundance of these lithotypes and sublithotypes in the Nittany Formation are indicated.

At the initiation of this study the writer had hoped to find intervals in the Nittany Dolomite that (1) were characterized by one or possibly several dolomite lithotypes, and (2) could be traced southwestward from Bellefonte along its outcrop belts. No interval of significant thickness was found to be characterized by dolomites of a particular lithotype or sublithotype. Dolomites of the various lithotypes and sublithotypes recognized in this study occur in a repeating manner throughout the formation. However, sand- and silt-size quartz grains were observed in beds of dolomite in the lower and upper part of the Nittany Formation at all sections measured, but these grains were observed only rarely in dolomite beds in the middle part of the formation. Thus, the lithologic separation of the Nittany Dolomite into three members is based on the presence versus absence of silt- and sand-size quartz

* Geologist, Texaco Inc., New Orleans, Louisiana.

grains in dolomite beds. The lower Forge Union and upper Etna Furnace Members have many dolomite beds containing quartz grains whereas few if any dolomite beds in the middle Shoenberger Member contain quartz grains.

Attention is given to the nature of and probable influence of various environments on the composition, texture and accumulation of the original carbonate sediment, the development of sedimentary structures, and the alteration of the original calcitic sediments to dolomite. In addition, the paleogeography of central Pennsylvania during the deposition of the Nittany Dolomite is considered.

The Nittany Dolomite and stratigraphically adjacent formations in central Pennsylvania are correlated with formations of similar age in several nearby regions of the eastern United States.

INTRODUCTION

PURPOSE AND SCOPE

The limestones and dolomites of the Lower Ordovician Beekmantown Group reach a maximum thickness of about 4,000 feet in central Pennsylvania. At Bellefonte, in Centre County, the Beekmantown rocks are separated into four formations that express large-scale alternation from limestone to dolomite and vice versa. The lowest formation is the Stonehenge Limestone, and this is overlain by a sequence of dolomites approximately 1,200 feet thick called the Nittany Dolomite, the subject of this study. Above the Nittany in turn is a body of limestone, the Axemann Limestone, over which is a body of dolomite, the Bellefonte Dolomite. The stratigraphic position of the Nittany Dolomite within the thick sequence of Cambro-Ordovician carbonate rocks in central Pennsylvania is illustrated in Figure 1. This study is one of a series on the stratigraphy of Lower and Middle Ordovician carbonate formations carried out by graduate students in the Department of Geology and Geophysics at the Pennsylvania State University under the guidance of Dr. F. M. Swartz.

The Nittany Dolomite, since 1911 when it was named by Ulrich, has been mapped from southwest of Bellefonte, the type locality, to Friends Cove in central Bedford County. Throughout the area, descriptions of sections of the Nittany Dolomite have been limited and generalized. In the present study, the writer has investigated in detail four sections in the vicinity of Bellefonte, including that at Ulrich's (1911) type locality, together with eight sections farther south to the vicinity of Lutzville in Bedford County. On the basis of observations made at these sections, data concerning the lithologic and paleontologic features of the Nittany beds are presented. This information is then used as the basis for an interpretation of the lateral variations developed in the Nittany southwest of Bellefonte. In the course of this work, samples of representative dolomites were studied in etched and thin section in order to understand relations of lithologic and paleontologic characteristics, and with the further

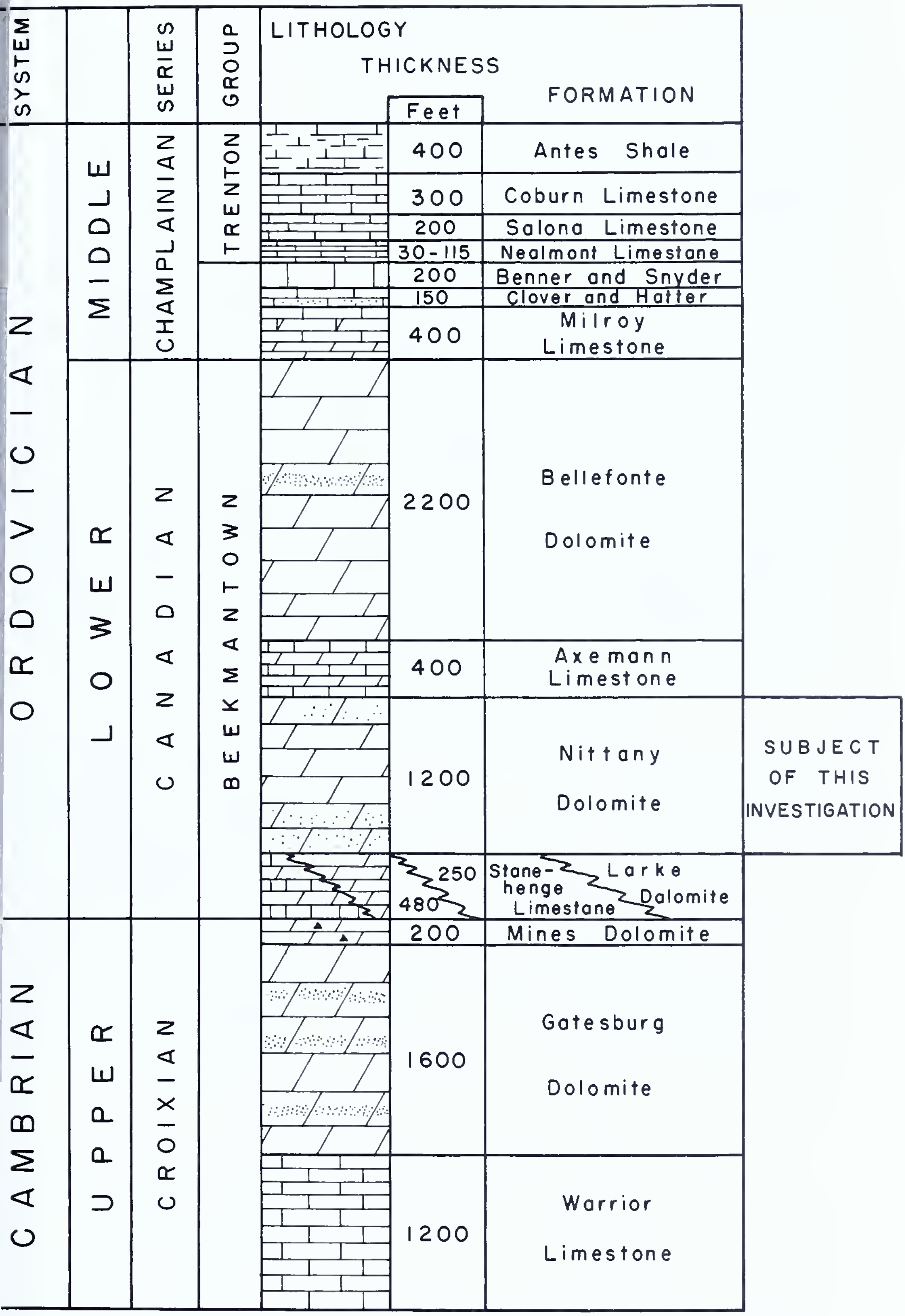

Figure 1. Stratigraphic position of the Nittany Dolomite within the Cambrian and Ordovician carbonate section of central Pennsylvania. Thicknesses obtained from Butts (1936), Donaldson (1959), Thompson (1963), and Lees (1964).

hope of obtaining information concerning possible modes of origin, environments of deposition, and post-depositional changes undergone by the carbonate rocks that exist today as dolomites.

At the time Ulrich (1911) named the Nittany Dolomite, he suggested that the formation thins southwestward from Bellefonte and may possibly disappear near Martinsburg in Morrison Cove. In a later paper (1938) he suggests that the Nittany should be separated into three formations which he proposed to identify with the Longview, Jefferson City and Cotter Formations of Tennessee, Missouri and Arkansas, and thus drop the name Nittany Dolomite. The information obtained during this study indicates that the Nittany does thin somewhat southwestward from Bellefonte to Lutzville but does not disappear; the writer believes that the name Nittany Dolomite should be retained and used as originally employed by Ulrich.

In recent years, interest in the Lower and Middle Ordovician carbonate rocks of central Pennsylvania has been renewed in part due to an increase in activity by the petroleum industry. Wells drilled for oil and gas are reported to have penetrated the Nittany Dolomite and adjacent rocks in southwestern Bedford County and north-central Centre County. Interest is also related to the search for water sources to satisfy the continually increasing requirements of this region.

AREA OF INVESTIGATION

The areas of surface distribution of the Lower Ordovician Beekmantown Group in central Pennsylvania, as well as the locations of measured sections of the Nittany Dolomite, are shown in Figure 2. Maps showing detailed locations of all measured sections are given in Appendix B, although only the three most detailed section descriptions are included in this report. For detailed descriptions of the other nine sections the reader is referred to the original thesis (Spelman, 1965). Outcrop belts of the Nittany are developed in a series of eroded anticlinal valleys that are at this latitude the most northwesterly valleys of the Valley and Ridge physiographic province and that lie along the course of the anticlinorium known as the Nittany Arch.

HISTORICAL REVIEW

The extensive outcrops of limestone in the valleys of central Pennsylvania, exposed by the erosion of a succession of tightly folded anticlines and synclines, were described by Rogers in 1858. Of special interest to this study are his descriptions of the Auroral Magnesian Limestone, ". . . the lowest exposed formation in the region, (which) occupies by far the greater part of the surface of all the principal valleys, extending from

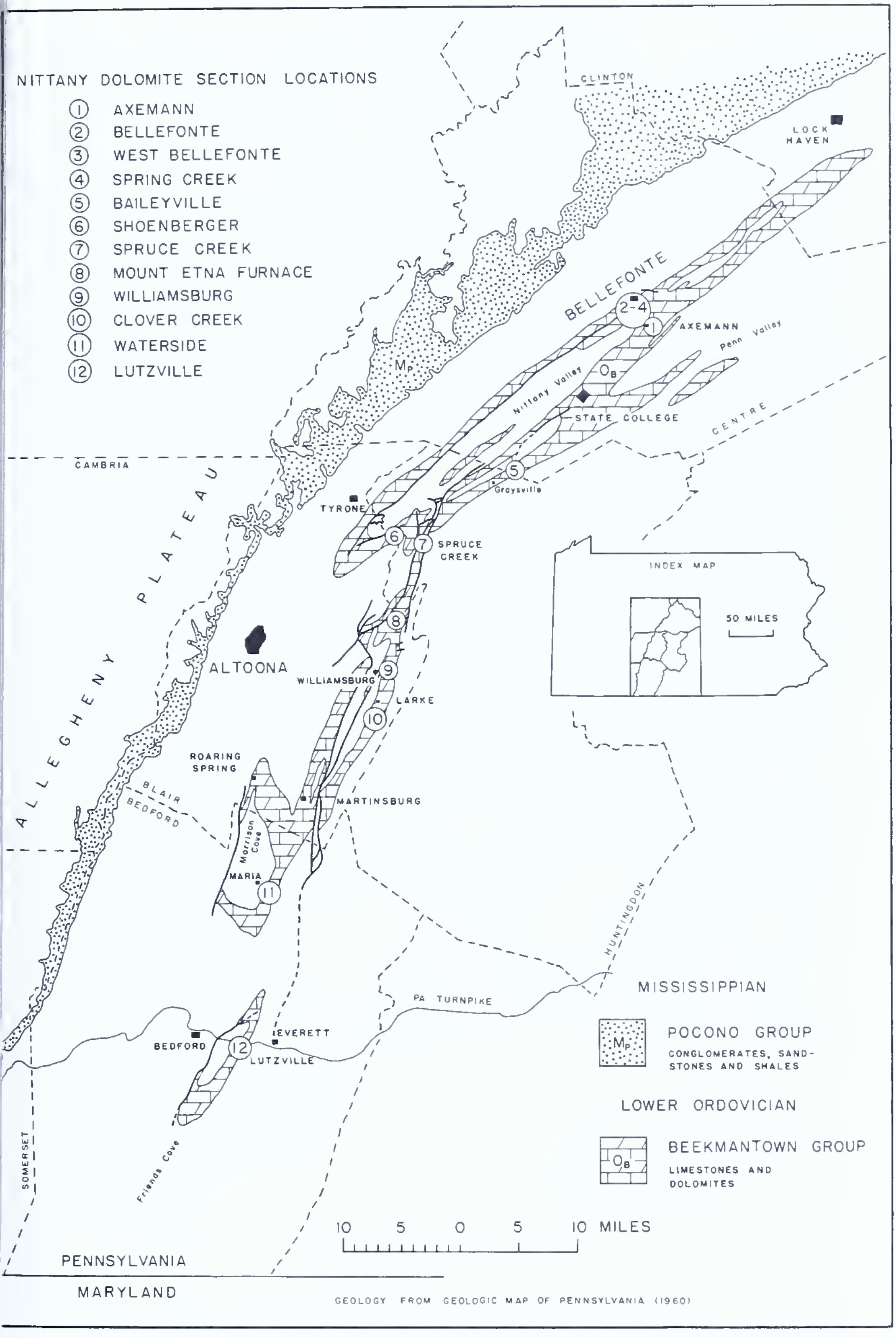

Figure 2. Surface Distribution of Lower Ordovician Beekmantown Group in central Pennsylvania.

the anticlinal axis in Kishacoquillas, Nittany, and the other valleys, to within a few hundred yards of the base of the encircling ridges" (Rogers, 1858, p. 470). At Bellefonte, in Nittany Valley, he measured a section of Magnesian Limestone, 5,400 feet thick, and subdivided it into a lower "Non-fossiliferous portion" and an upper "Fossiliferous Division." The sequence of rock later called the Nittany Dolomite occurs within the "Non-fossiliferous portion."

In 1903, Collie published the description of a section containing fossils of Ordovician age that began at the tollgate one mile south of Bellefonte and ended at the Narrows of Milesburg gap north of the town. Collie assigned the lowermost 4,800 feet of section containing three distinct fossiliferous horizons to the Beekmantown Group. This sequence corresponds closely to the "Non-fossiliferous Portion" of the Calciferous or Auroral Magnesian Limestone.

Ulrich (1911) studied the exposures at Bellefonte in greater detail and observed that the Beekmantown Group, previously described by Collie as composed entirely of limestone, contained two thick bodies of magnesian limestone. He located the fossiliferous zones described by Collie, found additional fossiliferous intervals, and subdivided the Beekmantown into four formations. Limestones containing fossil horizons A-1 and A-2 of Collie were referred to the Stonehenge Limestone, for which the type locality is near Chambersburg, Pennsylvania, 60 miles south of Bellefonte, in the southeastern part of the Valley and Ridge Province. Collie's fossil horizon A-3 occurs within the upper limestone sequence, the Axemann Limestone. The thick sequence of magnesian limestones occurring between these relatively pure fossiliferous limestone units was assigned to the Nittany Dolomite. The name probably was taken from the Nittany Valley Iron Company's furnace, then located within or close to the outcrop belt of the Nittany. The upper magnesian Limestone sequence was named the Bellefonte Dolomite.

Ulrich measured a section of the Nittany Dolomite 1,215 feet thick at Bellefonte. In his discussion he separates the Nittany Dolomite into four units of description and lists the fossils found within each.

Butts, in his report on the Bellefonte quadrangle (Butts and Moore, 1936), separated the Nittany Dolomite at Bellefonte into nine units of description. He listed fossils that he and Ulrich had collected, but located them only as occurring in either the upper or lower part of the formation. In addition, Butts (1939, 1945) has provided brief descriptions for the Nittany Dolomite in quadrangles southwest of Bellefonte.

The Cambro-Ordovician carbonate rocks of central Pennsylvania, and especially those exposed in the vicinity of Bellefonte, have been described briefly in several guidebooks for recent field trips (Swartz and others, 1955; Krynine, 1960; Wagner, 1963).

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The writer is deeply indebted to Dr. F. M. Swartz who suggested the problem, guided the investigation and critically reviewed the thesis. Dr. E. G. Williams and Dr. C. Thornton reviewed parts of the manuscript, and their suggestions and criticisms are gratefully acknowledged. Information derived from discussions with John A. Lees, also a graduate student in the Department of Geology and Geophysics, concerning the Axemann Limestone was extremely valuable. Dr. E. A. Yochelson and Dr. W. Sando of the United States Geological Survey helped in the identification of gastropods and brachiopods collected during this study. Financial assistance provided by the Mineral Conservation Section and the Department of Geology and Geophysics at The Pennsylvania State University enabled the writer to undertake and complete this investigation.

PETROGRAPHY

INTRODUCTION

The Nittany Dolomite is composed almost entirely of the rock dolomite. In this study dolomite is defined as a carbonate rock containing greater than 90 percent by volume of the mineral dolomite in the carbonate fraction; in the field it is differentiated from limestone by its feeble reaction to a 10 percent, or approximately 2 N, solution of hydrochloric acid.

About 1 percent of the Nittany Dolomite, however, is composed of beds of shale and chert, and nodular chert. Shale beds range in thickness from a thin film to about one inch; they are considerably more fissile than adjacent dolomite beds. Bedding breaks or bedding surfaces in thick dolomite sequences commonly result from the weathering of thin shale beds. Chert beds seldom exceed one foot in thickness. Beds that can be traced laterally for short distances are seen to be highly variable in thickness as the result of either an undulating lower or upper surface, and in many instances a bed may pinch out entirely. Nodules of chert occur in dolomite beds throughout the Nittany Formation.

In the following discussion the morphological varieties of the various carbonate and noncarbonate minerals that comprise dolomites found in the Nittany Formation are discussed. Attention is then given to the occurrence and arrangement of these minerals in dolomite. This discussion includes a description of both the textural aspect of dolomite and the sedimentary structures developed in dolomite during the accumulation and lithification of the original carbonate sediment. Finally, the various types of dolomite that occur in the Nittany Formation are grouped into ten dolomite lithotypes and five sublithotypes. The criteria used to make this

lithotype classification are presented, and the characteristics and abundance of these lithotypes and sublithotypes in the Nittany Formation are described.

NATURE OF ROCKS IN THE NITTANY FORMATION

Composition

Carbonate Minerals

Dolomite

Four morphological varieties of the mineral dolomite occur in samples from the Nittany Dolomite. These varieties are differentiated on the basis of size and shape of the dolomite crystals and of their manner of occurrence. This classification is used primarily to describe crystalline dolomite in thin section and is not to be confused with the scheme employed to describe the predominant crystal size in hand specimens of dolomite (See Fig. 3). The varieties recognized were proposed by Folk (1952).

Microcrystalline dolomite (Plate 1, Figures 1 and 2)—Crystals of microcrystalline dolomite, in thin section, are characterized principally by their small size and lack of rhombohedral crystal faces. They range in size from 5 to 40 microns, and in any particular sample are fairly well sorted.

In hand specimens microcrystalline dolomite is characterized by minute glimmering surfaces on a freshly broken rock face. The color of the rock varies from very light grey to medium grey depending on the amount of insoluble material present. In general, clay and silt-size quartz, if mixed with microcrystalline dolomite, tend to lighten the color of the rock. Microcrystalline dolomite forms nearly the bulk of most finely crystalline dolomites.

On the basis of shape alone it is impossible to determine whether each microcrystalline dolomite particle was moved about on the sea floor before its accumulation and consolidation into a rock. However, in many finely crystalline laminated dolomites there is evidence that the dolomite particles have undergone some degree of movement. The laminae in these laminated dolomites commonly are layers that contain a relatively large percentage of silt-size quartz grains and clay. Microcrystalline dolomite particles are generally larger in the laminae containing silt-size quartz grains than in the overlying quartz-free laminae (Plate 1, Figure 2). Apparently the silt-size quartz grains and the larger carbonate grains settled to the bottom first so that graded bedding is developed. Subsequent dolomitization results in the recrystallization of the carbonate particles, and alters their outline and removes any evidence based on shape that the carbonate material has undergone movement on the sea floor. Thus, the

individual particles of microcrystalline dolomite, and the other morphological varieties of dolomite that are observed in thin section, are called crystals and not grains.

The term grains is applied to relatively large particles, such as oolites, carbonate rock fragments and pellets, that have been moved about on the surface of sedimentation. In thin section these dolomitized particles seem to be made up of an interlocking network of dolomite crystals. It is noteworthy that in a few special cases a dolomite particle could be referred to as either a crystal or a grain on the basis of the definitions previously stated. For example, dolomitized pelmatozoan plates, in thin section, commonly occur as a unit crystal, and they probably were moved about on the surface of sedimentation before being incorporated into the sediment.

Xenomorphic dolomite (Plate 1, Figures 3 and 4)—Xenomorphic dolomite particles are devoid of rhombohedral crystal faces and have a crystal size greater than 0.04 mm. They are thus larger than crystals of microcrystalline dolomite, and their lack of the rhombohedral crystal faces and manner of occurrence distinguishes them from sparry dolomite. Xenomorphic dolomite crystals range in size from 0.04 to 1.0 mm, with the average between 0.1 to 0.2 mm. Since it occurs in a wide range of sizes it is convenient to separate xenomorphic dolomite into two crystal size classes; fine xenomorphic dolomite crystals range from 0.04 to 0.250 mm and coarse xenomorphic dolomite crystals are larger than 0.250 mm. Xenomorphic dolomite crystals are generally equant to subequant; they form a tight interlocking network of clearly distinct crystals. The color of these crystals varies from colorless to light brown.

Xenomorphic dolomite crystals make up the bulk of most medium and coarsely crystalline dolomites. It is also commonly found replacing oolites and pellets (Plate 7, Figures 1 and 3). Outlines of these relict limestone particles are often preserved because impurities or organic material contained in the original carbonate color the replacing dolomite. Oolites usually appear as dark brown circles, and pellets as smaller, more elongated dark brown spots. One, and occasionally two, concentric rings may be preserved in the dolomitized oolites, but radial lines were never observed. Dolomite crystals replacing oolites cut across the original concentric layers and are commonly coarser than the dolomite crystals of the surrounding interstitial material (Plate 1, Figure 3).

Idiomorphic dolomite (Plate 1, Figures 5 and 6)—Crystals of idiomorphic dolomite have well developed rhombohedral outlines. They range in size from 0.02 to 0.80 mm, but average between 0.05 to 0.15 mm. Idiomorphic dolomite crystals are divided into two crystal size classes:

fine idiomorphic dolomite ranges from 0.02 to 0.250 mm and coarse idiomorphic dolomite is greater than 0.250 mm. The crystals occur as rhombs, but in some cases adjacent crystals destroy or alter a rhombic face and change the outline of the idiomorphic crystal to hypidiomorphic. Many of the coarse idiomorphic crystals have centers of dark-brown colored rhombs, and in some rhombic "growth rings" are developed from the center outward to the margin (Plate 1, Figure 6). The color of idiomorphic crystals varies from light to dark brown to colorless. In general, the larger crystals tend to be lighter colored and they show some cleavage that is usually best developed near the margin.

It is difficult to distinguish idiomorphic dolomite from xenomorphic dolomite in hand specimens. In some instances samples of coarsely crystalline dolomite composed of coarse idiomorphic dolomite weather in such a way that the individual rhombs are etched in relief. The resulting surface is extremely rough, and if rubbed by the finger yields sand-size "grains," each grain being a dolomite rhomb. Dolomites composed of idiomorphic dolomite make up only a small percentage of the Nittany Formation.

Sparry dolomite (Plate 1, Figures 7 and 8)—In thin section crystals of sparry dolomite range in size from 20 microns to 0.7 mm and are clear, free of inclusions, and colorless. They generally form an interlocking network of distinctly outlined crystals whose margins vary from idiomorphic to xenomorphic, but are most commonly hypidiomorphic. Rhombohedral cleavage is fairly well developed in the larger crystals.

In hand specimens sparry dolomite is generally coarsely crystalline and colored milky grey. Sparry dolomite is found filling cavities (Plate 1, Figure 7) and fractures (Plate 1, Figure 8), and originates in these open areas as a direct precipitate of dolomite. The size of the sparry crystals in cavities generally increases outward from the cavity wall. Sparry dolomite was also observed filling the chambers of small low-spired gastropods. Crystals of this variety of dolomite make up a very small percentage of dolomites in the Nittany Formation.

Calcite

Sparry calcite.—The only calcite observed in the Nittany Dolomite occurred filling either fractures or solution cavities. These calcite crystals are milky white to light grey and nearly all are greater than 0.25 mm in diameter. Sparry calcite crystals are more coarsely crystalline, have a more perfectly developed rhombic shape, and are lighter colored than sparry dolomite crystals. The sparry calcite that fills fractures or cavities in dolomites of the Nittany is precipitated directly from ground water solutions rich in calcium carbonate. The calcium carbonate most likely is

derived from the solution of limestone beds from overlying and underlying formations.

Noncarbonate Minerals

Quartz

Quartz is the most abundant noncarbonate mineral found in the Nittany Dolomite. Based on mode of origin two types of quartz, detrital and authigenic, are recognized. Detrital quartz is subdivided into sand- and silt-size grains. Three varieties of authigenic quartz are distinguished: isolated crystals, overgrowths, and vein or cavity quartz.

Detrital Quartz.—Detrital quartz grains are derived from the erosion of pre-existing rocks on an emergent land mass located outside the basin of accumulation of the carbonate sediment, and are carried as individual particles into the basin of deposition. The size of detrital quartz grains is described in terms of Wentworth's size classification: sand-size grains range from 0.063 mm to 2.0 mm in diameter and silt-size grains are less than 0.063 mm in diameter. Most quartz grains contained in dolomites of the Nittany are believed to be detrital.

A. *Sand-size grains* (Plate 2, Figures 2, 4-8; Plate 3, Figures 1 and 3, 7 and 8). Most of the sand grains observed range in size from 0.063 to 1.0 mm but average about 0.4 mm in diameter. These grains usually are well rounded and spherical to subspherical. The degree of roundness generally decreases with decreasing grain size with the result that silt-size grains are typically angular rather than rounded. The surfaces of sand grains studied in insoluble residues are usually frosted and pitted (Plate 5, Figures 7 and 8). In thin section dolomite crystals surrounding quartz grains were seen penetrating the edge of the grains and in many instances replace some of the silica. The frosted surfaces of the grains from the insoluble residue are believed to result in part from such penetration of adjoining dolomite crystals and not necessarily from abrasion.

Sand-size quartz grains seen in thin section commonly are colorless and contain few inclusions. Quartz overgrowths on sand grains were observed only rarely.

Sand-size quartz grains were observed in rocks of all lithotypes and sublithotypes recognized by the writer, but they occur most commonly in finely crystalline laminated dolomites and medium-coarsely crystalline granular dolomites. They occur either concentrated along laminae and bands or are distributed rather randomly throughout the rock; in the latter case they are described as "floating" grains as they appear to be suspended in a matrix of dolomite crystals. A few sand-size grains are usually found in laminae that are made up almost entirely of silt-size quartz grains. Quartz sand grains, on close inspection, can be recognized on a

clean weathered surface of dolomite. The more sand a dolomite contains the more easily its presence is recognized, but even if the dolomite contains only a few widely scattered floating grains a close examination will reveal their presence.

B. *Silt-size grains* (Plate 2, Figures 1-3; Plate 3, Figures 1-6). Silt-size quartz grains commonly range from 0.04 mm to 0.063 mm in diameter. In thin section they are colorless and their outlines are generally angular. Silt-size quartz grains commonly are concentrated into laminae in light-grey, finely crystalline dolomites. Dolomite crystals intermixed with quartz silt in such laminae are larger than dolomite crystals in quartz-free laminae. Silt-size quartz grains in combination with argillaceous material form dark-colored streaks and irregular-shaped mottled areas in many medium and coarsely crystalline dolomites. Floating silt-size quartz grains are rarely found in the more coarsely crystalline dolomites.

Sand- and silt-size quartz grains occur in many dolomite beds in the lower and upper part of the Nittany; their presence in these dolomites is the criterion used to separate the Nittany Dolomite into a lower and upper sandy member and a middle nonsandy member.

Authigenic Quartz.—A. *Isolated quartz crystals* (Plate 5, Figure 9). Quartz crystals were observed in several insoluble residues but were not seen in any of the thin sections examined. In residues the loose quartz crystals are commonly singly and rarely doubly terminated, and range from 0.05 mm to slightly over 2 mm long. The crystals vary from clear to cloudy, and their crystal faces are commonly encrusted with quartz overgrowths or are pitted. Aggregates of quartz crystals were observed in a few residues. The individual quartz crystals in the aggregate are cemented together by silica. Commonly only one end of the larger quartz crystals is perfectly terminated by rhombohedral faces. The nonterminated end is usually a fracture surface. Most of the larger quartz crystals probably grew outward from the walls of solution cavities. The smaller crystals are usually doubly terminated and probably grew within the carbonate sediment.

B. *Quartz overgrowths* (Plate 3, Figures 7 and 8). Authigenic quartz overgrowths were seen in only two thin sections, but were observed coating at least a few grains in each insoluble residue that contained a large number of grains.

In both thin sections the overgrowths were developed on detrital quartz nuclei in regions where the quartz grains were closely packed and commonly come in contact with one another. Where the quartz grains are loosely packed and surrounded by dolomite crystals very few had overgrowths. The overgrowths develop in optical continuity with the nucleus and form crystal faces of different sizes and degree of perfection depending on the amount of interference from the surrounding dolomite crystals.

C. *Vein or cavity quartz.* Vein quartz was observed in only a few insoluble residues. Such quartz occurs in irregular shaped aggregates that are bounded by fracture surfaces. They have all the attributes of normal quartz and were precipitated in veins or solution cavities in the host dolomite. Quartz was seen only rarely in the field filling solution cavities and fractures in dolomites.

Chert

Folk (1950) studied the nature and distribution of chert in limestone and dolomites of the Beekmantown Group in central Pennsylvania. He showed that these cherts consist of three varieties of quartz; normal quartz, chalcedonic quartz and microcrystalline quartz (Plate 4, Figures 1 and 2). Normal quartz displays all the properties generally associated with quartz. It occurs as an interlocking network of xenomorphic to idiomorphic crystals that range from 0.05 to 0.30 mm in diameter and fills cavities and veins in chert masses. Chalcedonic quartz has a microscopically fibrous appearance. It commonly fills cavities in chert masses and is deposited in successive bands outward from the wall of the cavity. Where the cavity wall is extremely irregular the bands are often broken into small semi-circular segments of spherulitic chalcedony. Folk (1950) describes microcrystalline quartz as consisting of individual microcrystals that range in diameter from 0.002 mm to 0.05 mm and average 0.005 mm. Individual quartz particles are approximately equant but irregularly shaped; they unite with other particles to form an interlocking network. Each particle displays undulose extinction. Microcrystalline quartz forms the bulk of most chert and is the form of silica that replaces such relict limestone particles as brachiopod shells and oolites (Plate 4, Figures 7 and 8).

Chert was observed in the field in the form of thin beds, nodules and irregularly shaped patches. It is divisible into two general types, massive chert and disseminated chert. Massive chert occurs in lumps or layers large enough to be seen by the unaided eye. Disseminated chert is distributed throughout the rock and can be seen only after the dolomite sample has been dissolved by acid.

A. *Massive chert.* Massive chert occurs in a variety of shapes and in sizes large enough to be seen in the field. Nodular chert is the variety most commonly seen in the Nittany Dolomite (Plate 14, Figures 5 and 6). Outlines of nodules range from elliptical to extremely irregular. Nodules are commonly 2 to 3 inches long and 0.5 to 1 inch wide, but some exceed 12 inches in length and 3 inches in thickness. They are light to medium grey or dark brownish grey and appear cryptocrystalline on freshly broken surfaces. Most nodules are structureless but some are laminated and at several localities laminae can be traced from the host dolomite through the nodular chert.

Two special types of nodular chert commonly occur in the Nittany Dolomite. Dolomoldic nodular chert occurs in the lower part of the Nittany Formation at the West Bellefonte, Mount Etna and Williamsburg sections. This chert contains euhedral rhombohedra of dolomite that are distributed throughout a matrix of microcrystalline quartz (Plate 4, Figures 3 and 4). Although individual dolomite crystals seldom touch one another, in most such chert they are connected by a network of hairline fractures. The dolomite commonly forms 5 to 15 percent of the entire nodule. Dolomoldic chert receives its name from molds left in chert after the dolomite rhombs have been dissolved away.

Nodular oolitic chert was observed at many horizons throughout the Nittany Formation at nearly all sections measured (Plate 4, Figures 5-8; Plate 5, Figures 1-3). In most specimens the concentric structure and nucleus of the oolite were destroyed during the replacement of the original carbonate by silica and all that remains is a circle of microcrystalline quartz (Plate 5, Figure 2). However, in several chert samples both the nucleus and concentric layers of the oolite are delicately preserved (Plate 4, Fig. 7).

Bedded chert was observed less commonly than nodular chert in the Nittany Formation. The chert beds seldom exceed several inches in thickness. However, several beds ranging from one to four feet in thickness were observed near the top of the Forge Union Member at the Mount Etna, Williamsburg (Plate 14, Figures 2 and 8), and Waterside sections. With the exception of these unusually thick units, chert beds seldom extend laterally for more than a few feet at an exposure.

B. *Disseminated chert*. Disseminated chert occurs between dolomite crystals and is either distributed throughout the rock or is concentrated into irregular patches. In either form it is usually necessary to etch a surface of the dolomite sample in hydrochloric acid to determine if this variety of chert is present, and if so in what amount. Disseminated chert is divisible into two general types, interstitial chert and chert aggregates. Interstitial chert fills spaces between dolomite crystals (Plate 10, Figure 2). If the dolomite is completely dissolved away interstitial chert is left behind in the form of weak, spongy-looking, irregular lumps that are pitted by rhombohedral openings impressed in the chert by the surrounding dolomite crystals. Where the chert-filled interstices are contiguous the residue occurs as larger continuous skeletal networks of dolomoldic chert. Interstitial chert occurs most commonly in medium-coarsely crystalline dolomite.

Chert aggregates are dense concentrations of microcrystalline quartz and silt-size quartz grains (Plate 5, Figures 5 and 6). Whereas interstitial chert forms only 5 to 10 percent of the bulk of a dolomite sample, chert aggregates may make up as much as 25 percent of the dolomite sample. Chert aggregates are best seen in insoluble residues from dolomite samples

that have been thoroughly leached with hydrochloric acid. The chert aggregate usually retains the shape of the dolomite fragment (Plate 5, Figure 4). The strength of the aggregate varies with the amount of pore space, the degree of cementation, and the amount of interstitial clay material. If the aggregate is firmly cemented by silica it will break apart only under a moderately strong force, such as firm pressure applied with a probe. The insoluble residues from most dolomite samples consist almost entirely of chert aggregates and debris from chert aggregates. The small pores in chert aggregates are commonly rhombohedral in shape. Chert aggregates occur most commonly in finely and medium crystalline dolomite.

Feldspar

Grains of detrital feldspar were observed in several dolomite thin sections. These grains occur with silt- and sand-size quartz grains in arenaceous laminae of many light-grey, finely crystalline, laminated dolomites (Plate 3, Figure 2). The grains are clear, subequant and nearly perfectly rounded, and range from 0.05 to 0.20 mm in diameter. The feldspar grains observed in thin section display the polysynthetic twinning or "gridiron" structure typical of microcline. Although no point count was made to determine the amount of feldspar associated with quartz grains in sandy laminae, the quartz-feldspar ratio is estimated to be about 100 to 1.

X-ray diffraction patterns were obtained for the clay-size fraction of the insoluble residue from nine dolomite samples. These nine samples represent a variety of crystallinity sizes, colors and sedimentary structures. All nine samples contained small amounts of microcline but some samples contained more than others. However, there did not appear to be any relationship between microcline content and dolomite rock type.

Clay Minerals

Nearly all dolomites in the Nittany Dolomite contain some clay minerals. This observation is based on the binocular microscopic examination of insoluble residues of over 300 dolomite samples from the Nittany. In order to determine the nature of the clay mineral, or minerals, the clay-size fraction from insoluble residues of nine dolomite samples was sedimented onto glass slides and examined with X-rays. The X-ray diffraction pattern for each of these samples had a fairly strong peak at 8.8° 2θ. Weaver (1953), who carried out a detailed study on the clay-size fraction of insoluble residues from Middle Ordovician limestones near State College, found that the X-ray diffraction patterns from all but one of his samples gave a fairly strong peak at a spacing of 10 A°, or 8.8° 2θ. According to Weaver (1953) this peak is caused by a nonexpanded dioctahedral 2:1 clay mineral, illite.

There was no indication on the diffraction patterns that any of the nine dolomite samples contained kaolinite or montmorillonite.

In general, lighter colored dolomite, especially light grey laminated or structureless dolomite, contains more insoluble clay material than does medium or dark grey dolomite. Apparently, the light color is due in part to clay mineral impurities.

WENTWORTH GRADE SCALE (mm)	CRYSTALLINITY		GRANULARITY	
		USED IN THIS STUDY		
	Falk's (1959) carbonate crystal size classification	Dolomite crystal size based on the average size of dolomite cleavage faces	Grain size of granular components, mostly relict limestone particles	Grabau's (1924) clastic grain size classification
pebbles	64mm extremely coarsely crystalline 4mm	very coarsely crystalline	dolarudite	calcirudite
2.0 very coarse sand	very coarsely crystalline		dolarenite	very coarse calcarenite
1.0 coarse sand	coarsely crystalline	coarsely crystalline		coarse calcarenite
1/2 medium sand				medium calcarenite
1/4 fine sand	medium crystalline	medium crystalline		fine calcarenite
1/8 very fine sand				very fine calcarenite
1/16 silt	finely crystalline 0.016mm very finely crystalline	finely crystalline	dololutite	calcisiltite
1/256 clay	aphanocrystalline			calcilutite

Figure 3. Crystallinity and granularity classification for dolomites from the Nittany Formation.

Pyrite

Pyrite was observed in hand specimens, thin sections and insoluble residues of many dolomite samples. It occurs as individual cubes or grains, or as aggregates of grains, in light- to dark-grey, finely to coarsely crystalline dolomite. Much of the pyrite has altered to lumps of yellowish-brown limonite. Small, black, irregular-shaped grains that have a glassy luster and red streak were observed in several insoluble residues. They are composed of an indefinite hydrous iron oxide and are an alteration product of pyrite. Limonite-rich chert nodules occur in the Forge Union Member of the Nittany Dolomite in the vicinity of Bellefonte and Baileyville. Pyrite occurs most commonly in dolomite beds in the Shoenberger Member of the Nittany Dolomite at the Shoenberger section, and in the Etna Furnace Member of the Nittany at the Mount Etna and Waterside sections.

Texture

Introduction

The terminology used to describe dolomite rock types in the Nittany Dolomite is based on observations made on hand specimens in the field. Some few samples require additional study before they can be adequately described and must, therefore, be examined further in the laboratory.

Crystallinity

A freshly broken surface of a hand specimen of dolomite, when rotated in sunlight, appears to sparkle. This sparkle is caused by the reflection of light from broken cleavage faces to the observer's eye. Crystallinity, or crystal size, in this study refers to the average size of dolomite cleavage faces in a hand specimen. Dolomites of the Nittany Formation are grouped into four crystal size classes. In Figure 3 the limits of each crystal size class are shown and a comparison of the limits of these classes with the Wentworth scale is made.

Crystallinity was measured in the field by comparing the unknown sample with specimens whose average crystal size had been previously determined in the laboratory and which represented each crystal size class. For ease of handling the standard specimens were mounted onto a card.

The crystal size classification proposed above was established for use in the Nittany Dolomite. It may be applicable to dolomites in other formations but it is not necessarily a satisfactory scheme for describing the crystallinity of all varieties of carbonate rocks.

Granularity

Granularity and grain size are terms that refer to discrete carbonate particles that were moved about on the surface of sedimentation before

their final incorporation into the sediment. Many dolomite samples in the Nittany Formation contain such relict limestone particles as oolites, pellets, bioskeletal debris, and rock fragments. Although these particles apparently have been altered in composition by the dolomitization of the host limestone, in many samples their outlines have been nearly perfectly preserved. Dolomites containing these grains have a granular texture, and depending on the average grain size are described by the terms dololutite, doloarenite and dolorudite, a terminology patterned after the scheme developed by Grabau (1924). This classification system is shown in Figure 3.

The terms crystallinity and granularity refer to distinctly different items. A dolomite description will always contain a reference to crystallinity or crystal size, whereas only those dolomite samples displaying a granular texture will be described in terms of granularity or grain size.

Granular Textures

In thin section dolomites from the Nittany Formation consist of interlocking dolomite crystals of various shapes. These range from euhedral to highly irregular, but none of the shapes suggest that the dolomite erystals have been moved about on the surface of sedimentation. None of the crystals have rounded or abraded outlines. The original carbonate material quite probably was moved about before reaching the area where it was finally consolidated, but the abraded outlines typically developed were destroyed during dolomitization. However, outlines of larger particles, such as oolites, pellets, bioskeletal debris and rock fragments, are preserved in some dolomites. The terminology used in this study to describe carbonate grains is similar to that developed by Folk (1952).

Oolites (Plate 6, Figures 1, 3, 5, 7 and 8; Plate 7, Figures 1, 2, 4 and 7).

Oolites are spherical or ellipsoidal bodies that have either a concentric or radial structure, or both. These internal structures are often destroyed by dolomitization so that oolites in dolomite samples lack radial structure; concentric rings are poorly preserved if present at all. In thin section oolites commonly appear as "ghosts." Oolites in dolomite are recognized by their size, shape, and sorting characteristics. They range from 0.2 mm to 0.5 mm in diameter. Their shape is commonly spherical, but they may be elongate to conform to the shape of the nucleus. The nature of the nucleus is often destroyed by dolomitization, but sand-size quartz grains and pelmatozoan plates were commonly observed. Oolites are generally well sorted except where they occur as the matrix between larger rock fragments. Dolomite samples containing oolites usually contain less than 10 percent insoluble residue.

Oolites are also found in chert where they are partially or completely replaced by microcrystalline quartz, but their concentric structure is com-

monly obliterated. In some samples, however, the concentric structure is delicately preserved.

Pellets (Plate 6, Figure 2; Plate 7, Figures 2 and 3).

Small, perfectly rounded carbonate grains that range in outline from spherical to elliptical are called pellets. Pellets are differentiated from oolites by their small size and lack of internal structure. They range from 0.04 mm to 0.2 mm and average approximatcy 0.08 mm in diamcter. They lack the concentric structure of oolites, and in thin section appear as homogeneous light- to dark-brown grains.

Pellets originate in several ways. They represent reworked fecal material extruded by small mud-eating organisms (Hatch and others, 1938). Leighton and Pendexter (1962) suggest that pellets may be grains of micrite (term proposed by Folk, 1959).

Pellets are nearly impossible to recognize in a dolomite hand specimen. Pelletal dolomites are medium or coarsely crystalline and commonly contain other granular particles such as oolites and bioskeletal debris. Positive identification can be made only if the dolomite sample is studied in thin section.

Pelletal dolomites contain a small percentage of such insoluble material as silt-size quartz grains and clay. They are commonly laminated or banded and in thin section are faintly cross-bedded. These features suggest that pellets were deposited by currents that were swift enough to sort and concentrate the grains along laminae and to remove finer grained material such as silt and clay.

Rock Fragments (Plate 6, Figures 5-8; Plate 7, Figures 4 and 5).

Grains derived by the erosion of previously deposited carbonate sediments are called rock fragments. In this study the term rock fragments corresponds to the term intraclasts proposed by Folk (1959, p. 4) for ". . . fragments of penecontemporaneous, usually weakly consolidated carbonate sediment that have been eroded from adjoining parts of the sea bottom and redeposited to form new sediment. . . ."

Rock fragments range from coarse silt-size to pebble or boulder size. The smallest fragments, observed in thin section, are tiny grains of microcrystalline dolomite, and they occur with silt-size quartz grains in laminae of many finely crystalline dolomite samples. The largest fragments observed in the field range from 2 mm to 2 inches in diameter. Rock fragments occur more abundantly and with greater frequency in medium and coarsely crystalline dolomite.

Bioskeletal Grains (Plate 6, Figures 4, 5 and 8; Plate 7, Figures 5-8).

Bioskeletal grains occur in many medium and coarsely crystalline dolomites. The types of fossils commonly found include gastropods, pelmato-

zoan plates and brachiopods. These forms range in size from 0.1 mm to about 1 inch, depending on the type of fossil. In general, shells of gastropods and brachiopods show little evidence of abrasion, whereas pelmatozoan plates appear to have been broken and the edges rounded. During dolomitization of the host rock the carbonate shell also is altered. However, in some dolomite samples the fossils were replaced by silica before dolomitization of the host rock with the result that their original form is almost perfectly preserved. Brachiopod shells and sponge spicules are commonly faultlessly replaced by silica, whereas gastropod shells are imperfectly replaced; silicification of pelmatozoan plates was not observed. Organic material within the shell is moved to and concentrated along the margin during dolomitization of the calcium carbonate shell and forms a dark line that delimits the boundary of the fossil. In thin section the dolomitized shell is relatively clear and colorless when compared to the surrounding dolomite cement and matrix.

Dolomites that contain fossils commonly incorporate other types of grains. Oolites and pellets commonly occur with fossils, and rock fragments and sand-size quartz grains have been found on occasion.

Sedimentary Structures

Method of Classification

Dolomites commonly contain noncarbonate impurities, such as silt-size quartz grains, clay and chert, that are distributed throughout the rock or concentrated into definite patterns. The dolomite crystal size of a rock may be nearly uniform or there may be areas in the specimen that are either coarser or finer than the surrounding dolomite crystals. These concentrations of noncarbonate impurities and regions of different crystal size are produced during the accumulation and compaction of the original carbonate sediment, and are referred to as sedimentary structures.

Terminology used for sedimentary structures describes shape and arrangements of the nonuniformity in composition or texture. Dolomites are divided first on the basis of absence of or presence of structure into two groups, structureless and structured. Structured dolomites are further subdivided into four classes; laminated, mottled, streaked or granular. Although photographs of acid-etched sections are used to illustrate the types of sedimentary structures recognized in this study, these structures commonly are well developed on naturally weathered dolomite surfaces.

Structureless (Plate 8, Figure 1; Plate 9, Figures 1 and 2; Plate 10, Figures 1 and 2).

Structureless dolomites have no recognizable sedimentary structure. Dolomites of this variety generally have a nearly uniform crystal size and

contain very little insoluble material. However, some structureless dolomites contain a relatively high percentage of interstitial chert that is distributed uniformly throughout the rock. The chert is nearly the same color as the dolomite so that it is difficult to recognize interstitial chert unless the sample is at least partly dissolvea in hydrochloric acid.

Structured

Laminated (Plate 8, Figure 2; Plate 9, Figures 3 and 4; Plate 10, Figures 3 and 4).—Laminae are layers in a sedimentary rock recognizably different from the layers directly above and below, and are parallel, or nearly so, to the bedding of the rock. Layers up to 2 mm thick are called laminae and layers ranging in thickness from 2 mm to 2 inches are bands. Laminae result from changes in composition, grain size or crystal size, or combinations of these. For example, laminae in most light-grey, finely crystalline, laminated dolomites contain a high percentage of silt- and sand-size quartz grains, and the dolomite crystals intermixed with the quartz silt and sand are coarser than the dolomite crystals in the quartz-free layers. The laminae in a few samples of coarsely crystalline dolomite are composed of linear concentrations of interstitial chert.

Most laminae are oriented parallel to bedding and are continuous for at least several feet. However, some laminae are oriented at a low angle to bedding and are only several inches long, in which case they are described as irregular and discontinuous.

Streaked (Plate 8, Figures 5 and 6; Plate 9, Figures 5 and 6; Plate 10, Figures 7 and 8).—Thin, irregular and discontinuous markings oriented at a high angle to the bedding of the dolomite are called streaks. Streaks vary in thickness from 0.1 mm to 1.0 mm and are commonly caused by accumulations of silt-size quartz grains, chert and clay, or any combination of these. Siliceous streaks are usually light grey, whereas siliceous-argillaceous streaks are commonly medium or dark grey. Streaks vary in shape from thin individual lines to an anastomosing network of lines that in places thicken and coalesce forming a blotch. Variation in thickness of the wider streaks is caused by a splitting of the streak into thinner branches.

Mottled (Plate 8, Figures 3 and 4; Plate 9, Figures 7 and 8; Plate 10, Figures 5 and 6).—A dolomite surface that has spots or blotches of a different color, composition or crystallinity is described as mottled. The shape of these blotches is usually very irregular, and their long dimensions vary from about 2 mm to 2 cm. Mottling is usually caused by differences in composition or crystal size. The most striking type of mottling is produced by concentrations of silt-size quartz grains, chert and clay. These darker colored materials are mixed together into large blotches that occasionally incorporate smaller patches of dolomite. Another type of mot-

tling is caused by differences in dolomite crystal size and results in extremely irregular-shaped patches that in places are pinched into short streaks. The type of mottling developed in dolomite beds that typically occur near the top of the Forge Union Member at Bellefonte is caused by concentrations of dark-grey oolite "ghosts" surrounded by light-grey dolomite interstitial material (Plate 8, Figure 8).

Granular (Plate 7, all Figures; Plate 8, Figures 7 and 8).—A dolomite containing oolites, pellets, bioskeletal debris or rock fragments is structurally classified as granular. In most cases the nature of the grains can be readily identified in hand specimen. Rock fragments are usually the largest and range in size from 5 mm to over 2 inches in the long dimension. Fossils are identified by their shape, and size varies with the variety. Oolites are recognized by their circular outline and uniformity in size, generally on the order of 0.5 mm. Pellets are too small to be recognized in hand specimens. Because of the textural change in the rock caused by dolomitization their identification can be made only in thin section.

Granular rocks generally contain more than one type of grain. In several dolomite specimens grains of bioskeletal debris and oolites form the rock framework, smaller pellets and sand- and silt-size quartz grains occur as the matrix, and the remaining empty spaces are filled with colorless fine xenomorphic dolomite.

CLASSIFICATION AND DESCRIPTION OF LITHOTYPES AND SUBLITHOTYPES

Method of Classification

The preceding discussion was based principally on observations made in the field on fresh and weathered surfaces of dolomite hand specimens. Although it was necessary to obtain additional information for a few samples in the laboratory by examining acid etched sections, thin sections and insoluble residues, nearly all dolomites in the Nittany Formation can be adequately described in the field for the purpose of this investigation.

On the basis of field descriptions ten dolomite lithotypes and five dolomite sublithotypes are recognized in the Nittany Dolomite. The lithotype classification is based on crystal size, and the nature of the sedimentary structure or granular texture displayed by the dolomite. Dolomites are first divided into two crystal size groups, finely crystalline and medium-coarsely crystalline. Each crystal size group is separated into five lithotypes on the basis of sedimentary structure and granular texture. The two granular lithotypes are further subdivided into sublithotypes based on the predominant type of grain.

If a dolomite contains rock fragments exceeding 2 mm in diameter and is also laminated the rock is described as a laminated dolorudite. Both terms provide information concerning the depositional history of the rock. Structural terms are used, when necessary, in combination with each other, and the modifier placed closest to the term dolomite indicates the structure believed to be most important in reconstructing the history of accumulation.

The lithotypes and sublithotypes recognized in this study, and the abundance of their representatives in the Nittany, are indicated in Table 1. Photographs of acid etched sections of representative lithotypes and sublithotypes are shown in Plates 11 and 12. For more detailed descriptions the reader is referred to Spelman (1965).

STRATIGRAPHY

INTRODUCTION

Order of Discussion

In the discussion to follow, the Nittany Dolomite is described first in the vicinity of the type section at Bellefonte. The type section, plus three nearby sections, are used to establish the presence of three lithologic members. The lithologic characteristics of formations directly above and below the Nittany Dolomite at Bellefonte, as well as locations of their contacts also are discussed. Attention is then given to changes in the physical and mineralogical characteristics of each member as observed in eight sections southwestward from Bellefonte to Lutzville, and to changes in the lithologic characteristics and boundaries of adjacent formations. Fossils collected in the Nittany Dolomite by previous workers and during this study are summarized, and their stratigraphic occurrence and method of preservation are indicated. Finally, the variation in thickness of the Nittany Dolomite and its members from Bellefonte southwestward to Lutzville is described and possible causes of this variation are considered.

Description of Lithologic Units in Measured Sections

The Nittany Formation is composed almost entirely of beds of dolomite. The criterion found most useful by the writer in separating the dolomites exposed at a section into units of description, commonly of the order of several feet in thickness, is dolomite crystal size. A unit as so treated is an interval of rock recognized in the field to be different from the rock that lies directly above and below it. The limits for the four crystal size groups,

TABLE 1.—Lithotype and sublithotype classification for dolomites from the Nittany Formation.

The abundance of representatives of each lithotype in the formation is also indicated. Sublithotypes are arranged in order of decreasing abundance.

	CRYSTAL SIZE GROUP	LITHOTYPES (Percent of crystal size group)	SUBLITHOTYPES		ESTIMATE OF ABUNDANCE (%) IN THE NITTANY DOLOMITE	REMARKS
NITTANY DOLOMITE	Finely crystalline dolomite 35-40%	I. Structureless (40%)			15%	Occurs more commonly in lower Forge Union and upper Etna Furnace Members than in middle Shoenberger Member. See Pl. 11, Fig. 1.
		II. Laminated (55%)			20%	Occurs abundantly in Forge Union Member and rarely in Shoenberger Member. See Pl. 11, Figs. 3 and 4.
		III. Mottled (<3%)			<1%	See Pl. 11, Fig. 7.
		IV. Streaked (<2%)			<1%	Occurs most commonly in the Forge Union and Etna Furnace Members. See Pl. 11, Fig. 2.
		V. Granular (<1%)	1. Rock fragments		<1%	See Pl. 12, Fig. 5.
		100%				
	Medium-coarsely crystalline dolomite 60-65%	VI. Structureless (25%)			15%	Occurs most commonly in the Forge Union and Etna Furnace Members. See Pl. 11, Fig. 2.
		VII. Laminated (5%)			3%	See Pl. 11, Figs. 5 and 6.
		VIII. Mottled (40%)			25%	Molds of fossils, silicified shells and oolites occur most commonly in dolomites representing this lithotype. See Pl. 11, Fig. 8; Pl. 12, Figs. 1 and 3.
		IX. Streaked (10%)			7%	Occurs most commonly in the Shoenberger Member. See Pl. 12, Fig. 4.
		X. Granular (20%)	2. Oolitic	(10%)	13%	Samples of granular dolomite typically incorporate at least two and sometimes all four grain types; they also commonly contain silt- and sand-size quartz grains. Fossils also occur in dolomites representing this lithotype. See Pl. 12, Figs. 6-8.
			3. Rock fragments	(2%)		
			4. Fossil debris	(<1%)		
			5. Pellets	(<1%)		
	100%	100%			100%	

finely, medium, coarsely and very coarsely crystalline dolomite, that are used in this study are shown in Figure 3. Dolomites of a crystal size group are then classified on the basis of their sedimentary structure as laminated, mottled, streaked, granular or structureless. Granular dolomites are further subdivided on the basis of carbonate grain type. In the description of each unit are added such items as color on both fresh and weathered surfaces, bedding thickness, and occurrence where present of sand-size and silt-size quartz grains, chert with emphasis upon its form, pyrite and fossils. The features used to describe each unit have in general been recognized in the field, but in some instances there has been some supplementation by use of data obtained in the laboratory.

To simplify the discussion that follows, the dolomites found in the Nittany Formation are described in terms of the ten lithotypes and five sub-lithotypes recognized in this study. These dolomite lithotypes and sub-lithotypes are listed in Table 1 and are illustrated in Plates 11 and 12.

Division of the Nittany Dolomite into Members

At the initiation of this study the writer had hoped to find intervals of dolomite in the Nittany Formation characterized by an abundance of one or possibly several dolomite lithotypes that could be traced southwestward from Bellefonte along its outcrop belts. Members were established on just such a basis in the underlying Stonehenge Limestone by Donaldson (1959). After several sections were measured it became apparent that the Nittany Dolomite could not be subdivided into members on the basis of dolomite lithotypes established according to the crystallinity and structural features of the dolomites. No interval of significant thickness is characterized by one particular lithotype or sublithotype, or combination of lithotypes. Dolomites of the various lithotypes and sublithotypes recognized in this study occur in a repeating manner throughout the formation.

There is, however, another basis on which a lithologic separation into members can be made. Sand-size and silt-size quartz grains were observed in dolomites of several lithotypes in the lower and upper part of the Nittany Formation at all sections measured, but these grains were only rarely observed in dolomite beds in the middle part of the formation. Thus, the lithologic separation of the Nittany Dolomite into three members is based on the presence versus absence of sand-size and silt-size quartz grains in dolomites representing the various lithotypes. The lower Forge Union Member and upper Etna Furnace Member are characterized by having many beds of dolomite containing sand- and silt-size quartz grains, whereas few, if any, dolomite beds in the middle Shoenberger Member contain sand- and silt-size quartz grains. As shown in the previous chapter, quartz grains commonly occur concentrated along laminae and bands in light-grey, finely crystalline dolomite, or as so-called "floating" grains in darker

more coarsely crystalline dolomite. Quartz grains also occur in nodular and bedded chert.

Other minor variations were observed in the Nittany Formation. The three members vary somewhat in the amounts of finely and medium-coarsely crystalline dolomite they contain. The amount and type of chert varies from member to member, and also varies laterally within a member. Narrow intervals within members may be characterized by the occurrence of dolomite of a particular lithotype or by cycles composed of dolomite of several lithotypes. The occurrence of fossils in dolomite beds of particular lithotypes within certain intervals is a special feature of one member. However, none of these features are as persistent, nor are they as easily recognized, as the variation in the content of silt- and sand-size quartz grains.

NITTANY DOLOMITE IN VICINITY OF BELLEFONTE

Type Section as Described by Ulrich and Butts

A brief four unit description of the Nittany Dolomite at Bellefonte was provided by Ulrich (1911) when he formally assigned the name. He recognized that the Nittany Dolomite is composed of magnesian limestones so that it contrasts with the relatively pure limestones of the underlying Stonehenge Limestone and the overlying Axemann Limestone. The description was somewhat expanded by Butts (1936) who recognized nine lithologic units of description for the Bellefonte section. Both Ulrich and Butts reported the occurrence of *Lecanospira ("Ophileta") complanata* and *Cryptozoon steeli* in the lower half of the Nittany Dolomite at the type section in Bellefonte.

In measuring the Beekmantown carbonate sequence at Bellefonte, Ulrich (1911) began his traverse near the axis of the Gatesburg anticline in the Upper Cambrian Mines Formation, and worked northwestward along the road connecting Axemann and Bellefonte, now Pennsylvania Highway 53. Ulrich does not give the precise location of his line of traverse, but it seems likely that after entering the town of Bellefonte the traverse continued westward along Mill Street, then northward along Water Street to the northern edge of town. This traverse would have taken him past Nittany Furnace, an iron furnace that since has been torn down, and which according to Butts (1936), was used by Ulrich as the source of the name for the formation.

Sections Located in the Vicinity of Bellefonte

In the present study, four sections of the Nittany Dolomite were measured and described at and in the vicinity of Bellefonte. The Bellefonte section was measured at the same locality as Ulrich's type section. Although

only the lower 600 feet and uppermost 100 feet are exposed here, it is quite possible that when Ulrich visited Bellefonte there were fewer buildings along Mill and Water Streets so that he was able to see more of the rock than can be seen today. Only the lower 50 feet are exposed at the Axemann section and the lower 150 feet at the Spring Creek section, whereas the lowermost 800 feet are exposed at the West Bellefonte section. The four sections lie within an area of four square miles. The Axemann section is 1.6 miles southwest of the Bellefonte section, and the West Bellefonte section and Spring Creek section are 0.8 and 1.1 miles southwest of the Bellefonte section, respectively. Since the Nittany Formation is not completely exposed at any one locality the following discussion of the Nittany in the vicinity of Bellefonte is based on the combination of exposures observed at the four sections.

In the discussion to follow, the important lithologic features of each member in the vicinity of Bellefonte are summarized. For a detailed description of each member of the West Bellefonte section, the reader is referred to Appendix B, and to Spelman (1965) for detailed descriptions of all four Bellefonte-area sections. Stratigraphic columns for each section, based on these detailed descriptions and drawn to a scale of one inch equals 40 feet, are shown in Plate 21.

Members of the Nittany Dolomite

Forge Union Member

Approximately 20 percent of the dolomites exposed in the lower Forge Union Member, 580 feet thick at Bellefonte, contain sand- and silt-size quartz grains. Dolomites representing nearly all lithotypes recognized in this study are arranged in a repeating manner throughout the member. However, because dolomites representing a few lithotypes occur more abundantly in certain parts of the member, and because other minor lithologic variations exist, for purposes of description the member is separated into three sequences of approximately equal thickness in the Bellefonte area.

The lowermost of the three sequences is 220 feet thick. Nearly two-thirds of the dolomites in this interval are finely crystalline and one-third are medium-coarsely crystalline. Approximately 60 percent of these two crystal size classes are structureless; the remaining 40 percent consists of finely crystalline laminated dolomite and medium-coarsely crystalline mottled or clastic dolomite with interbeds of structureless dolomite. The sequence is cyclic in that dolomites of the various lithotypes continually alternate with one another vertically in the section. (See Plate 21). The crystallinity of the dolomite beds varies regularly from finely crystalline to medium-coarsely crystalline to finely crystalline. However, the structure of

the units changes from structureless to the various types of structured dolomite in a completely irregular manner. Sand- and silt-size quartz grains occur only in a few beds of light-grey, finely crystalline, laminated dolomite. Several beds of dark-grey, coarsely crystalline, oolitic dolomite occur near the base of the sequence, but rocks of this lithotype occur more abundantly in each of the overlying sequences of the Forge Union Member. Nodular chert occurs in only one bed near the top of the interval, and no fossils were found.

More beds of dolomite contain sand- and silt-size quartz grains in the middle sequence, 220 to 430 feet above the base of the Forge Union Member than do dolomite beds in the lower and upper sequences. (See Plate 21). Most of the quartz grains occur in finely crystalline laminated dolomite, but quartz grains also were observed in a few beds of medium-coarsely crystalline structureless, mottled or oolitic dolomite and finely crystalline structureless dolomite. The sequence consists of approximately equal amounts of finely, medium, and coarsely crystalline dolomite. Lithotypes most commonly represented include finely crystalline laminated and structureless dolomite, and medium-coarsely crystalline mottled, structureless, laminated, and oolitic dolomite. Rocks of these lithotypes reoccur throughout the entire sequence.

In the upper part of this middle sequence beds of dark-grey, coarsely crystalline dolomite that are mottled, oolitic or structureless, are overlain by beds of light-grey, finely crystalline, laminated dolomite. The coarsely crystalline structureless dolomites commonly contain large masses of reddish-brown, iron-rich chert. The coarsely crystalline dolomite itself breaks apart into irregular masses that are extremely friable. The weathered surface appears "sandy," but the "sand" consists of dolomite rhombs loosened and left standing in relief by the weathering of the interstitial dolomite. Soil overlying beds of this type of dolomite is colored dark reddish brown and littered with residual chert. Nodular chert, either structureless or oolitic, occurs in medium-coarsely crystalline dolomite near the base of this interval. Outlines of small high-spired gastropods and larger low-spired gastropods, possibly *Lecanospira* sp., occur in coarsely crystalline dolomite near the top of the sequence.

Quartz grains in the upper sequence of the Forge Union Member, 430 to 580 feet above the base, are confined to beds of light-grey, finely crystalline, laminated dolomite. (See Plate 21). This sequence is characterized by a well-developed cyclicity between rocks of two lithotypes (Plate 13, Figure 1). These cycles consist of dark-grey, coarsely crystalline, mottled and oolitic, sometimes fossiliferous dolomite (Plate 13, Figure 5) and light-grey, finely crystalline, laminated dolomite (Plate 13, Figure 4). The contact between beds of coarsely crystalline and finely crystalline dolomite is irreguar and often transitional, while the finely crystalline-coarsely

crystalline contact is smooth and sharp (Plate 13, Figures 2 and 3). Fragments of finely crystalline dolomite are sometimes found incorporated in coarsely crystalline dolomite beds directly above the base of the coarser unit. About 80 percent of the upper sequence is composed of rocks of these two lithotypes. The remaining dolomites are finely crystalline structureless and medium-coarsely crystalline structureless or laminated. Chert occurs only rarely within the sequence. Specimens of *Lecanospira compacta, L.* cf. *L. salteri* and *Lecanospira* sp. commonly occur in dark-grey, coarsely crystalline, mottled and oolitic dolomite (Plate 13, Figure 5). This 150-foot interval appears to be the stratigraphic range for *Lecanospira* in the Nittany Dolomite of the Bellefonte area. *Ophileta* sp. and *Lytospira* sp. also occur in coarsely crystalline dolomite beds near the top of the member.

In summary, the basal Forge Union Member, 580 feet thick, is characterized by beds of dolomite containing sand-size and silt-size quartz grains. Although quartz grains were observed in dolomites representing several lithotypes they occur most commonly and in greatest abundance in light-grey, finely crystalline, laminated or structureless dolomite. The lower part of the member consists mainly of interbedded finely and medium-crystalline, structureless dolomite. Dolomites containing sand-size and silt-size quartz grains occur most commonly in the middle and upper parts of the member. Cycles consisting of light-grey, finely crystalline, laminated dolomite and dark-grey, coarsely crystalline, mottled and oolitic, or structureless dolomite are well developed near the top of the middle sequence and throughout the upper sequence of the member. Yellowish-brown, iron-rich chert commonly occurs near the top of the middle sequence of the member. Several species of *Lecanospira,* and *Ophileta* sp. and *Lytospira* sp. occur in dark-grey, coarsely crystalline, mottled and oolitic dolomite beds throughout the upper 150 feet of the Forge Union Member.

Shoenberger Member

Beds of dolomite containing sand- or silt-size quartz grains were not observed in the middle Shoenberger Member, 500 feet thick at Bellefonte. In addition, the Shoenberger Member contains only a few beds of light-grey, finely crystalline dolomite, a lithotype observed more commonly in the underlying Forge Union Member and overlying Etna Furnace Member. Slightly over 80 percent of the exposed rock is medium-coarsely crystalline dolomite. Most of these dolomites are mottled but some beds are structureless, streaked or laminated. Cycles consisting of finely crystalline and medium-coarsely crystalline dolomite are moderately well developed near the base of the member, whereas the middle part of the member consists almost entirely of coarsely crystalline, mottled or streaked dolomite. (See Plate 21). The upper 260 feet of the member is poorly

exposed in fields adjacent to the measured sections. However, the scattered exposures that are present contain few beds of finely crystalline dolomite. Chert occurs in only minor amounts, and outlines of small high-spired gastropods were the only fossils observed within this member.

Etna Furnace Member

The upper Etna Furnace Member, 130 feet thick at Bellefonte, lithologically resembles the lower Forge Union Member. It is made up of beds of light-grey, finely crystalline, laminated or structureless dolomite that commonly contain sand-size and silt-size quartz grains, and these beds are interbedded with medium-coarsely crystalline, mottled or structureless dolomite. (See Plate 21). Little chert and no fossils were observed.

Since the uppermost 400 feet of the Nittany Dolomite are so poorly exposed there is some question concerning the position of the base of the Etna Furnace Member. Better exposures might indicate that the base of the member should be lowered.

Formations Stratigraphically Adjacent to the Nittany Dolomite

In the Bellefonte region the Nittany Dolomite is underlain by the Stonehenge Limestone and overlain by the Axemann Limestone. Since these formations are composed largely of limestone, the upper and lower boundary with the Nittany Dolomite is rather easily located. However, southwest of Bellefonte, limestones in the Stonehenge and Axemann disappear with the result that the Nittany Dolomite is underlain by the Larke Dolomite in most of Blair, Huntingdon and Bedford Counties, and is overlain by the Bellefonte Dolomite or Axemann Limestone at sections measured in these three counties. In the discussion to follow the lithologic character of the Stonehenge Limestone and Axemann Limestone in the Bellefonte region is briefly described, and boundaries between these two formations and the Nittany Dolomite are established. In addition, fossils that occur near the top of the Stonehenge Limestone at Bellefonte, and which were used by the writer as an aid in locating the Stonehenge Limestone-Nittany Dolomite contact at Bellefonte and southwest of Bellefonte, are listed. The nature of the lithologic change which these two formations undergo southwestward from Bellefonte, and problems relating to the location of the upper and lower boundaries of the Nittany Dolomite caused by these lithologic changes, are discussed later in this chapter.

Stonehenge Limestone

Nature of the Stonehenge Limestone

Ulrich (1911) extended the use of the term Stonehenge Limestone to the Bellefonte area. Donaldson (1959) has studied the formation in de-

tail. He subdivided the Stonehenge Limestone into four members; in ascending order they are the Spring Creek, Graysville, Baileyville, and Logan Branch Members (Table 2).

TABLE 2—*Members of the Stonehenge Limestone in the vicinity of Bellefonte, Pennsylvania*

(From Donaldson, 1959)

	Member	*Thickness (feet)*	*Percent Dolomite at Bellefonte*
Stonehenge Limestone (465-482 feet)	Logan Branch	70-75	18
	Baileyville	210	26
	Graysville	145-160	1
	Spring Creek	40-50	26 to 47

The following descriptions of members of the Stonehenge Limestone are taken from Donaldson (1959). The Spring Creek Member is ". . . characterized by an approximately equal amount of 1- to 4-inch bedded fossiliferous oolitic calcarenite, dolomitic-mottled and -banded aphanitic limestone, and clayey and silty laminated dolomite" (p. 28). The Graysville Member is ". . . characterized by an abundance of calcirudite and calcarenite which interfinger and interbed with several 3-inch to 2-foot algal limestone beds" (p. 32). The Baileyville Member ". . . is characterized by a thicker-bedded, cherty, algal, aphanitic carbonate sequence lacking intraformational conglomerate except in small lens-shaped patches . . ." (p. 36), and small amounts of dolomite which give the rocks a mottled, streaked or banded appearance. Beds in the upper half of this member are sometimes mudcracked, sandy or oolitic. The Logan Branch Member lies directly below the Nittany Dolomite. Donaldson subdivided the member into two lithobodies. The lower 25 feet is characterized by ". . . pelmatozoan fine calcarenite interbedded with calcirudite . . ." (p. 41). Of special interest to this study is the uppermost 50 feet, a fossiliferous sequence of interbedded limestones and dolomites commonly referred to as the *Bellefontia* Zone due to the occurrence of this particular trilobite. This interval is characterized by ". . . fossiliferous, oolitic calcarenite. Occasional beds of intraformational conglomerate, dolomitic-mottled algal limestone and aphanitic limestone, and clay laminated finely crystalline dolomite are interbedded with this dominant rock type" (p. 41). Listed below are some of the fossils reported by Donaldson (1959) from the Logan Branch Member at Bellefonte. These fossils, together with lithologic criteria, were used to locate the Nittany Dolomite-Stonehenge Limestone contact in the vicinity of Bellefonte.

Trilobita
Bellefontia collieana
Gastropoda
Gasconadia putilla
Lytospira? multiseptarius
Ophileta sp.
Brachiopoda
Finkelnburgia cf. *F. wemplei*
Arthropoda
Ribeiria parva
Incertae Sedis
Tentaculites lowdoni

Nittany Dolomite-Stonehenge Limestone Contact

In the Bellefonte area the Stonehenge Limestone is composed of approximately 75 percent limestone interbedded with 25 percent dolomite, the dolomite occurring mostly in the lower 50 feet and upper 280 feet (Table 2). The overlying Nittany Dolomite is composed entirely of dolomite, with one exception. At the Axemann section a bed of aphanitic limestone, 2.8 feet thick, is separated from limestones containing *Lytospira? multiseptarius* and *Ribeiria parva* by 48 feet of dolomite beds.

Donaldson (1959, p. 43) places the Nittany Dolomite-Stonehenge Limestone contact ". . . at the lowest occurrence of coarsely crystalline dolomite." The writer prefers to locate the contact immediately above the highest limestone bed containing fossils typical of the *Bellefontia* Zone of the Logan Branch Member. According to this definition the aphanitic limestone bed at the Axemann section is considered to be within the Nittany Dolomite. Both definitions, however, result in a contact located at nearly the same stratigraphic position at Bellefonte.

Axemann Limestone

Nature of Axemann Limestone

To the blue-colored nearly pure and fossiliferous limestones that occur above the Nittany Dolomite at Bellefonte, Ulrich (1911) assigned the name Axemann Limestone. Ulrich provides only a generalized description of its lithology and lists the fossils he found from a section located in Bellefonte where the Axemann is 158 feet thick. Butts (1936) added some detail to this description when he observed that the limestones of the Axemann are interbedded with dolomitic limestones and dolomites. While mapping the Bellefonte quadrangle, Butts (1936) also observed that its thickness is highly variable. He reports a thickness of from 158 to 200 feet at Bellefonte, 50 to 200 feet at Mattern Junction, and about 500 feet in the vicinity of State College and Oak Hall.

A detailed study of the stratigraphy of the Axemann Limestone from Bellefonte to Waterside in north-central Bedford County, 59 miles southwest of Bellefonte, has been made by Lees (1964). Lees measured and described in detail several sections in the Bellefonte area. Here he found that the Axemann is approximately 400 feet thick and consists of from 15 to 40 percent dolomite interbedded with limestone. In addition, Lees reports that the limestones of the uppermost 150 feet are characterized by calcilutites whereas the lower 250 feet consist predominantly of calcarenites.

Lees measured a section of Axemann approximately 700 feet thick at Lamar, 14 miles northeast of Bellefonte. The Axemann Limestone thins to about 400 feet at Bellefonte, and continues to decrease in thickness southwestward from State College. It is 240 feet thick at Mount Etna and about 180 feet thick at Woodbury in north-central Bedford County. Lees reports that thinning is caused by the disappearance of the upper part of the Axemann.

Axemann Limestone-Nittany Dolomite Contact

In the Bellefonte area the contact between the Axemann Limestone and the Nittany Dolomite is placed at the base of the first limestone bed encountered above medium and coarsely crystalline, mottled and streaked dolomite beds in the Nittany Formation.

At several localities southwest of Bellefonte, however, the contact is not so easily defined because the Axemann Limestone completely disappears. The reason for this disappearance, and criteria used to establish the top of the Nittany Dolomite when the limestones of the Axemann are missing, are discussed later in this chapter.

NITTANY DOLOMITE SOUTHWESTWARD FROM BELLEFONTE TO LUTZVILLE, PENNSYLVANIA

Introduction

The three members of the Nittany Dolomite are recognized in sections southwestward from Bellefonte. However, because significant changes do occur in the lithologic character and thickness of each member, a description of the lateral variation is necessary. In the following discussion each member is traced, section by section, from Bellefonte to Lutzville in Bedford County, approximately 73 miles southwest of Bellefonte. Stratigraphic columns for each measured section, based on detailed section descriptions and drawn to a scale of 1 inch equals 40 feet, are shown in Plates 22 and 23. The description of the section to section change in the lithologic nature of each member is more easily followed if continued

reference to these two plates is made. A generalized stratigraphic cross section, Plate 24, shows the change in thickness of each member, and in a general way indicates the lateral variation of the lithologic character for each member. The stratigraphic position of all fossils collected in this study is also shown in Plate 24.

Members of the Nittany Dolomite

Forge Union Member

Many dolomite beds in the Forge Union Member contain silt- and sand-size quartz grains, and it is the occurrence of these quartz grains that distinguishes this member from the overlying Shoenberger Member. However, several other features serve to make the Forge Union Member the most distinctive of the three members recognized in the Nittany Dolomite. Several dolomite beds in the member contain unusually large amounts of nodular and bedded chert. Molds of *Lecanospira* occur in beds of dark-grey, coarsely crystalline dolomite and chert, and this fossil appears to be restricted to beds in the upper part of the member. Finally, the upper part of the Forge Union Member contains cyclic intervals composed of light- to medium-grey, finely crystalline dolomite and dark-grey, medium-coarsely crystalline dolomite. However, at sections southwest of Baileyville these cycles differ somewhat from the cycles developed in the upper 200 feet of the member at Bellefonte.

The Forge Union Member is incompletely exposed at Baileyville in an abandoned iron strip mine. Beds of dolomite are exposed in mounds left standing in relief above the mine floor. Most of the dolomite exposed is medium-coarsely crystalline mottled, oolitic or structureless, but several beds of light-grey, finely crystalline, laminated dolomite that commonly contain sand-size quartz grains occur interbedded with the more coarsely crystalline dolomite. Yellowish-brown irregular-shaped masses of iron-rich chert were found as residual material throughout the mine area. This chert is similar to chert found in the middle sequence of the member at Bellefonte.

The upper 260 feet of the underlying Stonehenge Limestone is lithologically similar to the Forge Union Member. This interval also consists of dark-grey, coarsely crystalline, mottled and oolitic dolomite with some interbeds of light-grey, finely crystalline, laminated dolomite. Iron-rich chert also is abundant on the surface overlying these dolomites. Silicified fossils of the type that occur in the Logan Branch Member of the Stonehenge Limestone at Bellefonte occur at the top of this interval in beds of dark-grey, coarsely crystalline, mottled and oolitic dolomite. The Nittany-Stonehenge contact is located above the dolomite beds that contain these fossils. If these fossils had not been found the dolomite beds would have

been placed in the Nittany Formation, and the Stonehenge Limestone-Nittany Dolomite contact would have been placed above the highest limestone bed located approximately 260 feet stratigraphically lower in the Stonehenge.

The uppermost beds exposed in the mine consist of dark-grey, coarsely crystalline, oolitic dolomite, and contain the silicified remains of *Diaphelasma pennsylvanicum* and an isolated endoceroid siphuncle.

Since no specimens of *Lecanospira* were found at Baileyville it is possible that at least the uppermost 150 feet of the member are concealed. If this concealed sequence is added to the interval exposed, then the member has approximately the same thickness as at Bellefonte, about 550 feet.

The Forge Union Member is missing at the Shoenberger section due to the Shoenberger fault. Beds of Stonthenge Limestone project into a concealed interval located at the position where dolomite beds in the Forge Union Member should be exposed.

The member is moderately well exposed at the Spruce Creek section (See Plate 22). Although most of the silt- and sand-size quartz grains occur in finely crystalline dolomite, significant quatities were observed in beds of medium-crystalline, mottled and structureless dolomite. Some thin beds of chert occur in medium-coarsely crystalline dolomite, and nodular chert occurs in the more finely crystalline dolomites (Plate 14, Figure 5). On the whole, less chert was observed here than at either Bellefonte or Baileyville. Cycles of dolomite similar to those observed in the upper part of the member at Bellefonte occur near the base and top of a sequence of sandy dolomites (Plate 14, Figure 3). No fossils were observed in the member here, but silicified fossils found in dolomite beds of the underlying Stonehenge Limestone were used as a guide in establishing a contact between these two formations. The top of the member is placed above the highest dolomite bed containing sand- and silt-size quartz grains, and is located about 340 feet above the base. Although slightly more than 200 feet of section are fairly well exposed above the uppermost sandy dolomite bed no quartz grains or fossils were found in this interval.

The Forge Union Member is well exposed at Mount Etna. (See Plate 22). Cycles consisting of beds of dary-grey, medium-coarsely crystalline, mottled or structureless dolomite and light-grey, finely crystalline, laminated dolomite that commonly contain sand- and silt-size quartz grains occur throughout the member. Beds of chert were found in coarsely crystalline dolomite near the top of the member. Large masses of chert up to six feet in diameter commonly occur as residual material. A few chert masses contain poorly preserved external molds of *Lecanospira*. Several of the coarsely crystalline dolomite beds are oolitic, and nodular chert contained in these beds preserves these relict grains. The Forge Union Member at Mount Etna is about 350 feet thick and is characterized by sandy dolomites,

cyclical dolomite sequences near the top of the member, bedded and nodular chert, and molds of *Lecanospira* sp. in chert. There is a close resemblance between the member at Mount Etna and the portion of the member exposed at Williamsburg.

The Forge Union Member is well exposed near Williamsburg. It is readily recognized by the occurrence of dolomite beds containing silt- and sand-size quartz grains (Plate 14, Figure 7), thick beds of chert (Plate 14, Figure 8), and molds of *Lecanospira* in chert. Cycles made up of beds of dark-grey, medium-coarsely crystalline, mottled or streaked dolomite and light-to medium-grey, finely crystalline, laminated or structureless dolomite occur in the upper two-thirds of the section (Plate 14, Figures 1 and 2). However, cycles at Williamsburg differ in several ways from cycles developed at Bellefonte. Beds of finely crystalline dolomite tend to be slightly darker colored and structureless. In addition, contacts between beds in a cycle are sharp; the transitional contact that is developed between beds of dark-grey, coarsely crystalline dolomite and overlying beds of light-grey, finely crystalline dolomite at Bellefonte was not seen in the Williamsburg section.

A bed of dolomite located about 160 feet stratigraphically above the base of the Nittany Formation contains silicified speciments of *Syntrophinella* cf. *S. cooperi, Ophileta* sp., *Lecanospira* sp., and badly damaged trilobite fragments. The occurrence of *Lecanospira* in chert at the top of the section and the overall similarity to the sequence exposed in the member at the Mount Etna section indicate that the top of the member is located only slightly above the highest exposed beds in the section.

Exposures in the lower part of the Waterside section indicate that the lithologic character and thickness of the Forge Union Member have remained essentially unchanged from Williamsburg. Thick beds of chert occurring within beds of coarsely crystalline dolomite form a ridge littered by masses of residual chert, many of which contain molds of *Lecanospira*. Below this ridge cycles consisting of beds of dark-grey, medium-coarsely crystalline dolomite and light- to medium-grey, finely crystalline, laminated and structureless dolomite that commonly contain quartz grains are exposed along a road cut (Plate 14, Figure 4). Contacts between these beds are sharp and not transitional. The member at this section is slightly more than 300 feet thick.

At Lutzville the member has increased in thickness to about 450 feet (See Plate 23). The lower half is mostly concealed, but masses of residual chert displaying structures that resemble *Cryptozoon steeli* occur abundantly in soil overlying this interval. Butts (1936) reports the occurrence of cryptozoon chert from the lower part of the Nittany Dolomite at Bellefonte and at other localities in the Tyrone and Hollidaysburg-Huntingdon Quadrangles. An occasional mass of chert resembling *Cryptozoon steeli*

has been found by the writer in these areas. Cryptozoon chert is usually found as residual material in fields, so the fact that most of the sections described in this study were located along highway or railroad cuts may explain the apparent absence of this form of chert.

Cyclical sequences of dark-grey, coarsely crystalline and light-grey, finely crytalline dolomite occur in the exposed part of the section; several of the finely crystalline dolomite beds contain silt- and sand-size quartz grains. Molds of *Lecanospira* were found in residual chert masses overlying beds of coarsely crystalline dolomite south of the Pennsylvania Turnpike along the north bank of Cove Creek. These dolomite beds project into a concealed interval located directly above dolomite beds containing quartz grains. The top of the member is located above the sandy dolomite interval and above the chert zone in which *Lecanospira* occurs.

In summary, the Forge Union Member thins from 580 feet at Bellefonte to 340 feet at Spruce Creek. (See Plate 24). Its thickness remains fairly constant southwestward to Waterside where it is about 320 feet thick, then thickens slightly to 450 feet at Lutzville. Southwest of Baileyville the upper portion of the member is characterized by cyclical sequences of dark-grey, medium-coarsely crystalline, mottled or structureless dolomite and light- to medium-grey, finely crystalline, laminated or structureless dolomite that commonly contains silt- and sand-size quartz grains. Contacts between these dolomite beds are sharp. Molds of *Lecanospira* occur in chert that is associated with coarsely crystalline dolomite. The Forge Union Member is the most distinctive of the three members recognized in the Nittany Dolomite.

Shoenberger Member

Few dolomite beds in the Shoenberger Member contain silt- or sand-size quartz grains. Dolomite cycles of the type found in the underlying Forge Union Member occur infrequently because beds of light-grey, finely crystalline, laminated dolomite are extremely rare. Thus, the member is also distinguished by the predominance of medium-coarsely crystalline mottled, streaked, or structureless dolomite.

The Shoenberger Member is best exposed at the Shoenberger section, the type section for the member (Plate 22). Beds in the lower part of the member are poorly exposed. The upper part of the member consists of beds of medium- to dark-grey or black, medium-coarsely crystalline dolomite that are mottled, streaked, or structureless. Some beds of light-grey, finely crystalline, laminated or structureless dolomite were observed but they make up only a small percentage of the total dolomite sequence exposed. Several beds of dark-grey, coarsely crystalline dolomite contain oolites, but these beds form only a small percentage of the member. Most finely and medium crystalline dolomite beds are darker colored than finely crystalline dolomite beds found in the underlying and overlying members.

These dark-grey to black, finely crystalline dolomites commonly contain masses of pyrite. Although relatively rare, some very thin beds of chert occur near the middle of the member. No fossils were found at this section. The Shoenberger Member at the Shoenberger section is lithologically similar to that portion of the member exposed at Bellefonte. At both sections no quartz grains were observed, and dolomite cycles of the type found in the Forge Union Member rarely occur. Chert is rare at both sections, and most dolomites are medium-coarsely crystalline, mottled, streaked, or structureless.

The member thins to about 450 feet at the Mount Etna section. More dolomite beds in the member are finely crystalline, but they are unlike the light-grey, finely crystalline dolomite of the Forge Union Member in that they are darker colored and are mottled or streaked rather than laminated. One bed of finely crystalline dolomite contains sand-size quartz grains, but no quartz grains were found throughout the rest of the member. Cycles consisting of finely and medium-coarsely crystalline dolomite occur, but due to the darker color and lack of structure of the finely crystalline dolomite they do not resemble cycles of the type found in the underlying Forge Union Member. Only a few beds of dolomite contain nodular or bedded chert. Pyrite occurs in several beds of dark colored finely crystalline dolomite. No fossils were found in the member at this section.

Southwest of Mount Etna, the member thins to about 300 feet at the Waterside and Lutzville sections. (See Plate 23). No silt- or sand-size quartz grains were observed at these sections, and less than 15 percent of the member is made up of finely crystalline dolomite. However, dolomites of this lithotype that do occur are light colored and laminated, and thus more closely resemble finely crystalline dolomite beds in members above and below than beds of finely crystalline dolomite that occur in the Shoenberger Member at sections to the northeast.

At the Waterside section medium-coarsely crystalline dolomite beds are commonly structureless, but several beds are mottled or streaked. Pyrite occurs in several beds of finely crystalline dolomite, and nodular and bedded chert occurs rarely near the middle of the member. A silicified endoceroid siphuncle identified as cf. *Clitendoceras* was collected near the top of the member.

The Shoenberger Member exposed at the Lutzville section varies little from the Waterside section. Nodular and bedded chert occurs in the upper part of the member, and endoceroid siphuncles identified as cf. *Proterocameroceras* and cf. *Platysiphon* were collected from medium-grey, coarsely crystalline, structureless dolomite beds located near the middle of the member.

In summary, the Shoenberger Member ranges in thickness from 500 to 600 feet between Bellefonte and Shoenberger; to the southwest it thins

to about 450 feet at Mount Etna, and continues to decrease in thickness to about 300 feet at Waterside and Lutzville. (See Plate 24). Silt- and sand-size quartz grains occur rarely in the member. Finely crystalline dolomites comprise only a small percentage of the total dolomite sequence, and they are typically darker colored than finely crystalline dolomites occurring in the underlying Forge Union and overlying Etna Furnace Members. Chert occurs in only minor amounts, and many darker colored, finely crystalline dolomite beds contain small quantities of pyrite. The only fossils collected from this member were assigned to three cephalopod genera, and these forms occur as silicified endoceroid siphuncles.

Etna Furnace Member

The Etna Furnace Member is lithologically similar to the Forge Union Member. In addition to having beds of dolomite that contain silt- and sand-size quartz grains, this member also has dolomite cycles similar to the type developed in the upper part of the Forge Union Member at Bellefonte. Only minor amounts of nodular and bedded chert occur throughout the member, and pyrite was found in a few beds of dark grey to black dolomite.

The Etna Furnace Member is well exposed at the Shoenberger section. (See Plate 22). Sand- and silt-size quartz grains occur in relatively large amounts in many beds of dolomite. The quartz grains occur with approximately the same frequency in beds of finely, medium and coarsely crystalline dolomite; these grains are sometimes concentrated into laminae or bands, but in several dolomite beds they are distributed uniformly throughout the bed and may comprise as much as five to ten percent of the unit. There is a well developed cyclical alternation between light to medium grey, finely crystalline dolomite and darker colored, medium-coarsely crystalline dolomite. These cycles resemble cycles developed in the upper part of the Forge Union Member at Bellefonte. However, beds of finely crystalline dolomite in the Etna Furnace Member are not as light colored as finely crystalline dolomite beds in the Forge Union Member. In addition, these finely crystalline dolomite beds are more likely to be structureless than laminated, and if they contain quartz grains the grains are commonly distributed uniformly throughout the bed rather than concentrated into laminae and bands. Many beds of the more coarsely crystalline dolomite are colored brownish grey and streaked, and several of these beds contain nodular chert having the same color as the host dolomite. Silicified fragments of *Tritoechia pennsylvanica* and *Orospira* sp., internal casts of high-spired gastopods, and silicified oxeakloster sponge spicules were found in several beds of brownish-grey, medium-coarsely crystalline, sandy and cherty dolomite in the lower part of the member.

The Etna Furnace Member is well exposed at the Mount Etna section

where it is about 300 feet thick. (See Plate 22). The name of the member is derived from Etna Furnace, an iron furnace located northwest of Mount Etna on the north side of Roaring Run. Sand-size quartz grains occur in finely, medium and coarsely crystalline dolomite beds with about the same frequency. The medium-coarsely crystalline dolomites are dark grey to black, and are mottled, streaked or structureless; many beds contain oolites or pebbles of dolomite. Finely crystalline dolomites are light to medium grey and laminated or structureless. Dolomites representing these lithotypes occur in cycles that somewhat resemble cycles in the upper part of the Forge Union Member. Fragments of silicified *Diparelasma* sp. and *Finkelnburgia* sp. were found in several beds of coarsely crystalline dolomite in the upper half of the member. Dolomitized specimens of *Ophileta* cf. *O. solida* and silicified internal molds of small high-spired gastropods were collected from a bed of dark-grey, coarsely crystalline, mottled and oolitic dolomite near the top of the member. Small amounts of nodular chert were observed in a few beds of finely to coarsely crystalline dolomite.

The Etna Furnace Member is poorly exposed at the Clover Creek section where it is about 240 feet thick. However, from the exposures available it is possible to observe that the dolomite beds at this section closely resemble those exposed at the Mount Etna section. Cycles composed of light- to medium-grey, finely crystalline, laminated dolomite and dark-grey, medium-coarsely crystalline, mottled or streaked dolomite are moderately well developed. Sand-size quartz grains commonly occur in the finely crystalline dolomite, but some grains also were observed in beds of medium-crystalline dolomite. No fossils were collected at this section.

The member decreases in thickness to 180 feet at the Waterside section. (See Plate 23). Cycles typical of the member are moderately well developed. Silt- and sand-size quartz grains occur in several beds of finely crystalline dolomite. Several beds of coarsely crystalline dolomite near the top of the member contain oolites or pebbles of dolomite. Both nodular and bedded chert occurs in small amounts throughout the Etna Furnace Member. A large cephalopod occurring near the top of the member was the only fossil found at this section.

The Etna Furnace Member increases in thickness to 320 feet at the Lutzville section. (See Plate 23). Dolomites containing sand-size quartz grains occur throughout the member. Most of the quartz grains are concentrated along laminae or bands in finely crystalline dolomite, but some grains were observed in more coarsely crystalline dolomite. Several beds of coarsely crystalline dolomite contain oolites or pebbles of dolomite. Cycles composed of beds of finely and medium-coarsely crystalline dolomite, and small amounts of bedded and nodular chert occur throughout the member. No fossils were observed. Beds of finely crystalline dolomite

located near the top of the member are typically medium to dark grey, and are darker than finely crystalline dolomite beds in the lower portion of the member. However, most of the sequence exposed at Lutzville closely resembles exposures of the member at the Mount Etna, Clover Creek and Waterside sections.

In summary, the Etna Furnace Member is characterized by beds of dolomite containing silt- and sand-size quartz grains, and by cycles of medium-light-grey to medium-grey, finely crystalline dolomite and dark-grey, coarsely crystalline dolomite. Cycles in the member, however, are not exactly like those developed in the upper part of the Forge Union Member due to the darker color of the finely crystalline dolomite and the absence of oolites in most beds of coarsely crystalline dolomite. Nodular and bedded chert occurs in only minor amounts. Silicified brachiopods, gastropods and sponge spicules, and dolomitized gastropods were collected from coarsely crystalline dolomite beds at the Shoenberger and Mount Etna sections.

The Etna Furnace Member is about 130 feet thick at Bellefonte. However, it is poorly exposed and the location of the lower boundary is subject to question. Southwest of Bellefonte, the member appears to thicken to 180 feet at Shoenberger, and increases to 300 feet at Mount Etna. (See Plate 24). It thins to 240 feet at Clover Creek, continues to thin to 180 feet at Waterside, and then thickens to 320 feet at Lutzville.

Formations Stratigraphically Adjacent to the Nittany Dolomite

Larke Dolomite

Nature of the Larke Dolomite

The Stonehenge Limestone underlies the Nittany Dolomite in Centre County and northern Blair County. Farther to the southwest, in central and southern Blair County and Bedford County, the Stonehenge disappears and the Nittany Dolomite is underlain by the Larke Dolomite.

Donaldson (1959) studied the Stonehenge Limestone at Bellefonte and along its outcrop belts to Williamsburg, about 40 miles southwest of Bellefonte, where the formation is completely missing. He collected nearly the same fossil assemblage from dolomite beds at the top of the Larke Dolomite in Blair County as he had collected from the *Bellefontia* Zone in the upper part of the Logan Branch Member of the Stonehenge Limestone at Bellefonte. In addition, he was able to trace oolitic calcarenite beds in the upper part of the Stonehenge Limestone at Bellefonte laterally into beds of medium and coarsely crystalline, oolitic dolomite in the upper part of the Larke Dolomite.

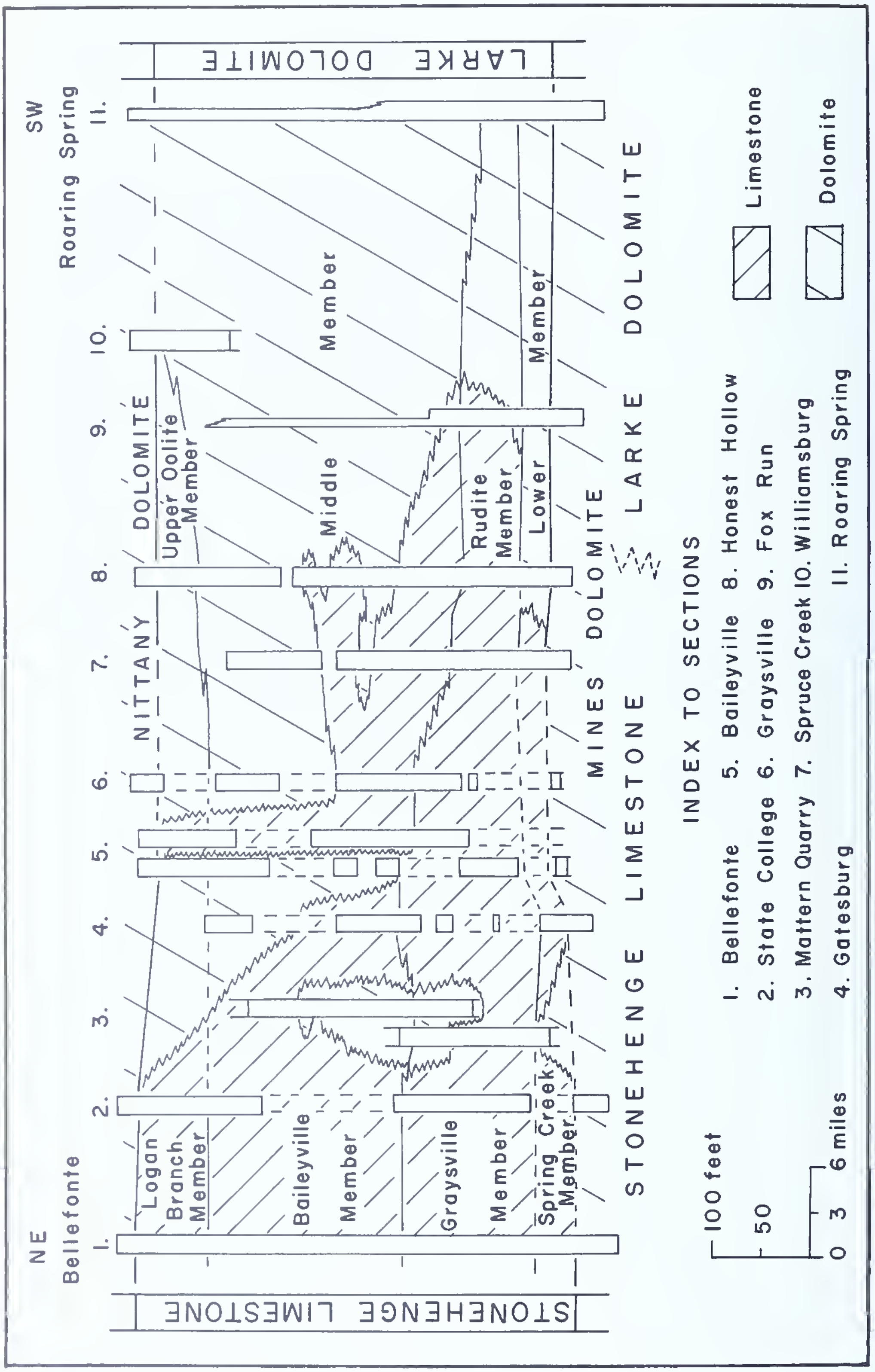

Figure 4. Generalized stratigraphic cross section of the Stonehenge Limestone and Larke Dolomite between Bellefonte and Roaring Spring, Pennsylvania (after Donaldson, 1959, Figure 12).

Donaldson's generalized stratigraphic cross section (Figure 4) shows limestones in the Stonehenge Formation interfingering with dolomites of the Larke Dolomite. He shows the upper Logan Branch Member changing to dolomite southwest of State College, and refers to the dolomite facies as the upper oolite member. The change in the name of this entire interfingering sequence from Stonehenge Limestone to Larke Dolomite is made by Donaldson southwest of his Honest Hollow section where beds of dolomite make up more than 50 percent of the sequence.

Nittany Dolomite-Larke Dolomite Contact

For several reasons, the Nittany Dolomite-Larke Dolomite contact is not easily located. Beds of dark-grey, coarsely crystalline, oolitic dolomite that are similar to dolomite beds occurring in the upper part of the Larke Dolomite occur throughout the Forge Union Member of the Nittany Dolomite. Sand- and silt-size quartz grains are distinctive elements in dolomite beds of the Forge Union Member, but they occur most commonly and in greatest abundance in the upper half of the member. Thus, it is necessary to use paleontologic as well as lithologic criteria to differentiate dolomites from these two formations. Many of the fossils reported by Donaldson from the *Bellefontia* Zone in the Stonehenge Limestone at Bellefonte were collected during this study at sections in and near Bellefonte, and at several sections where limestones in the Stonehenge have been either party or entirely replaced by dolomite. In addition, forms tentatively referred to as amphineuroid plates were discovered in the insoluble residues of dolomite samples that also contained fossils that are apparently restricted to the *Bellefontia* Zone.

Listed in Table 3 are some of the fossils identified by Donaldson from the *Bellefontia* Zone at Bellefonte, and all the fossils collected by the writer from this zone in both the Stonehenge Limestone and Larke Dolomite. The sections from which these fossils were collected, and the manner in which they are preserved is also indicated.

The Nittany Dolomite-Larke Dolomite contact is located above the highest bed of oolitic dolomite containing fossils that occur in the *Bellefontia* Zone at the top of the Logan Branch Member of the Stonehenge Limestone at Bellefonte. The only exception to this was made at the Waterside section. At this locality limestones reappear and interfinger with dolomites of the Larke Dolomite so that the Nittany Dolomite-Larke Dolomite contact is placed above the uppermost limestone bed.

Axemann Limestone

Axemann Limestone-Nittany Dolomite Contact

Throughout most of central Pennsylvania the Nittany Dolomite is overlain by the Axemann Limestone. When the Axemann is present the upper

TABLE 3.—*Occurrence, geographic distribution, and method of preservation of fossils in the Logan Branch Member (Bellefontia Zone) of the Stonehenge Limestone and upper oolite member of the Larke Dolomite in central Pennsylvania.*

	FAUNA	FORMS IDENTIFIED BY DONALDSON (1959)	SECTIONS* FROM WHICH FORMS WERE COLLECTED IN THIS STUDY												METHOD OF PRESERVATION OF SHELL	
			1	2	3	4	5	6	7	8	9	10	11	12	Silicified	Calcitic
TRILOBITA	*Bellefontia collieana*	X		2		4										X
GASTROPODA	*Gasconadia putilla*	X					5								X	
	Gasconadia sp.													12	X	
	Lytospira? multiseptarius	X	1			4	5		7	8	9				X	
	Ophileta sp.	X												12	X	
BRACHIOPODA	*Finkelnburgia* cf. *F. wemplei*	X													X	
	Finkelnburgia cf. *F. bridgei*						5			8					X	
ARTHROPODA	*Ribeiria parva*	X	1			4	5		7	8	9				X	X
INCERTAE SEDIS	*Tentaculites lowdoni*	X					5				9				X	
	Amphineuroid (?) plates Type I						5		7						X	
	Type II								7						X	
	Type III						5		7	8					X	
	Type IV													12	X	

* Measured

* For relationships to measured sections of Stonehenge-Larke nomenclature, see Figure 4.

1. Axemann
2. Bellefonte
3. West Bellefonte
4. Spring Creek
5. Baileyville
6. Shoenberger
7. Spruce Creek
8. Mount Etna
9. Williamsburg
10. Clover Creek
11. Waterside
12. Lutzville

boundary of the Nittany Dolomite, and the Etna Furnace Member, is placed at the base of the first limestone bed encountered above medium-coarsely crystalline dolomites of the Nittany Formation. The generalized stratigraphic cross section (Plate 24) was drawn using the lowest limestone bed in the Axemann as the datum. This was done with the understanding that although the lowest limestone beds at each section may not be exactly the same age, they probably were deposited at approximately the same time. The Axemann Limestone is missing at the Shoenberger and Lutzville sections and the Nittany Dolomite is directly overlain by the Bellefonte Dolomite. The basis on which the Bellefonte-Nittany contact is established will be discussed in the following section.

The thinning of the Axemann Limestone from 400 feet at Bellefonte to 180 feet at Woodbury in north-central Bedford County and its disappearance in several areas between these two sections is described by Lees (1964). At two localities he demonstrated that the disappearance of the limestone is the result of a facies change to dolomite.

At one locality 8 miles northeast of the writer's Shoenberger section, Lees measured a series of closely spaced sections between Graysville and Evergreen Farms, 1.4 miles southwest of Graysville on Pennsylvania highway 45 (Figure 5). Limestone is missing in the section closest to Graysville. The second section, one-half mile along strike to the southwest, contains about 30 percent limestone. One-half mile further to the southwest, the third section contains about 70 percent limestone, as does the fourth section at Evergreen Farms. At the second section from Graysville fragments of silicified *Tritoechia pennsylvanica* were found in dolomite beds 40 feet above a bed of dolomite containing sand-size quartz grains. Silicified fragments of *Tritoechia pennsylvanica* were found in limestones about 60 feet above the sandy dolomite bed at the third section. This sandy dolomite bed in the Nittany persists along the outcrop belt to Evergreen Farms. Here, limestones occur 30 feet above the bed of sandy dolomite, and specimens of *Tritoechia pennyslvanica* were collected about 100 feet above this sandy unit.

At another locality two miles south of Roaring Spring on the east side of Halter Creek, Lees (1964) was able to walk out along the outcrop belt a facies change from limestone to dolomite. He also collected a silicified specimen of *Ceratopea tennesseensis,* a form known to occur only in the Axemann Limestone or its equivalents, from a bed of dolomite 10 feet above an interval of sandy dolomites.

Bellefonte Dolomite

Bellefonte Dolomite-Nittany Dolomite Contact

At the two sections where Axemann Limestone is missing, the top of the Nittany Dolomite, and thus the Etna Furnace Member, is located at

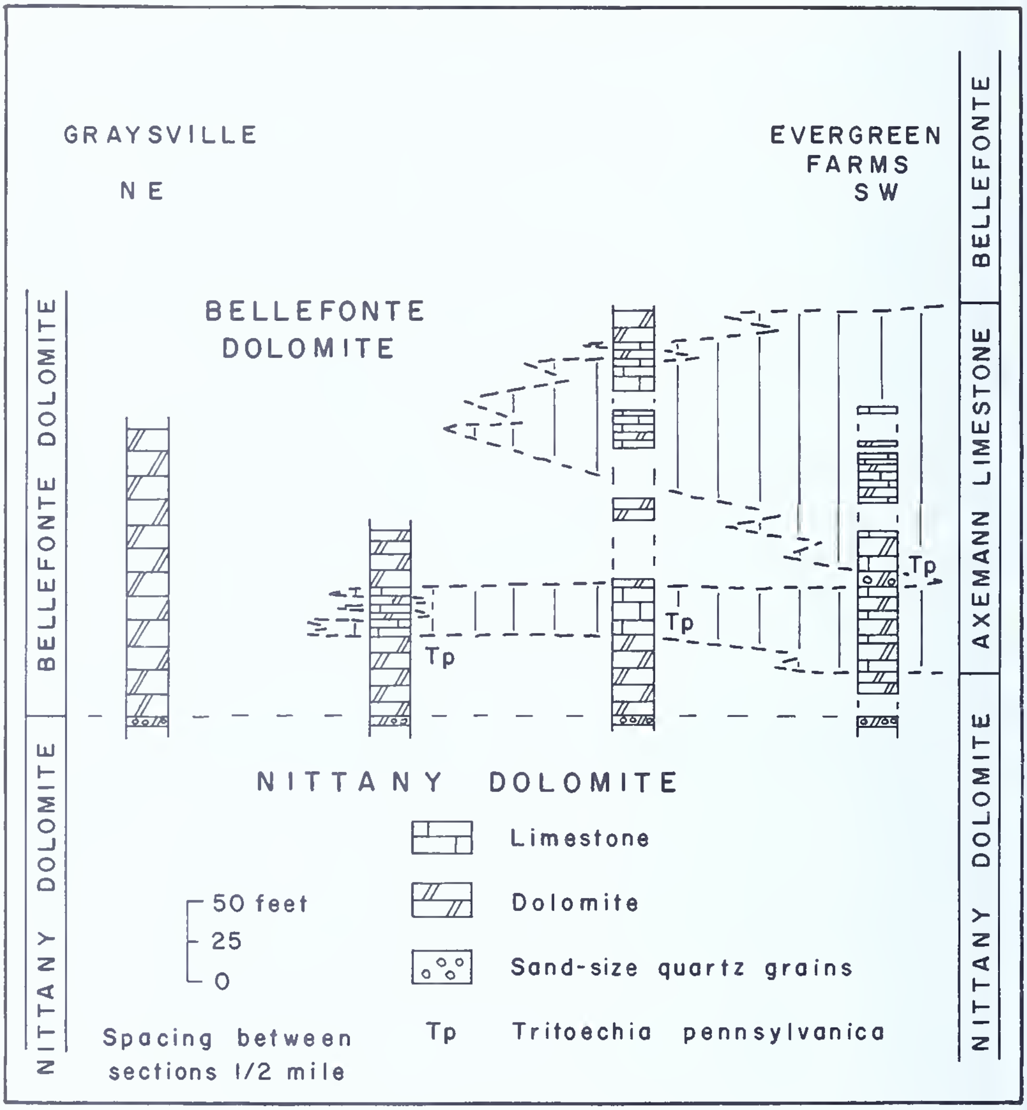

Figure 5. Generalized stratigraphic cross section of the Axemann Limestone between Graysville and Evergreen Farms, Huntingdon County, Pennsylvania. Data provided by Lees, personal communication.

the top of the uppermost bed of dolomite containing sand-size quartz grains. The Nittany Dolomite-Axemann Limestone contact is based on a lithologic change from dolomites to limestones, whereas the Nittany Dolomite-Bellefonte Dolomite contact is based on a change from dolomites containing quartz grains to dolomites free of quartz grains. In the generalized stratigraphic cross section (Plate 24) the top of the sandy interval, at the two sections where the Axemann Limestone is missing, is placed above the datum drawn immediately below the lowest limestone bed in the Axemann. According to this interpretation the upper part of sandy dolomite sequence is Axemann equivalent. Both lithologic and faunal evidence supports this hypothesis. Lees (1964) reports the occur-

rence of quartz grains in dolomites that occur interbedded with limestones at several sections of Axemann Limestone near Shoenberger. Although most of the sandy dolomites occur near the Axemann-Nittany contact, quartz grains were observed in dolomites up to 100 feet above the lowest limestone bed at his Spruce Creek section. Another line of evidence is based on the occurrence of *Tritoechia pennsylvanica* in several beds of dolomite near the base of the sandy Etna Furnace Member at Shoenberger. In a series of closely spaced Axemann sections between Graysville and Evergreen Farms, Lees (1964) found specimens of *Tritoechia pennsylvanica* in dolomites below the lowest limestone bed, in limestones, and in dolomites interbedded with limestones. (See Figure 5). Thus, it is possible that part of the Etna Furnace Member at Shoenberger, and possibly some of the overlying dolomite beds assigned to the Bellefonte Dolomite, are equivalent to the Axemann Limestone. If this interpretation is correct the Axemann Limestone disappears due to a facies change from limestone to dolomite.

The upper part of the Etna Furnace Member at Lutzville may also be Axemann equivalent. (See Plate 24). Quartz grains in dolomite beds that are interbedded with limestones were observed in the Axemann Limestone at the nearby Waterside section. Finely crystalline dolomites at the top of the Etna Furnace Member are darker than those typically developed in the lower and middle parts of the member. A third line of evidence is based on observations made by Knowles (1964). While mapping in north-central Bedford County he noticed that a zone of chert occurs near the base of the Bellefonte Dolomite throughout the area. At Lutzville the uppermost bed of sandy dolomite in the Nittany occurs slightly less than 250 feet stratigraphically below this chert zone. Estimates of the thickness of the Axemann range from 180 feet (Lees, 1964) to 203 feet (Butts, 1945). Since the exact position of the cherty zone above the base of the Bellefonte Dolomite is not known, the uppermost sandy dolomite beds in the Etna Furnace Member may be Axemann equivalent.

Where the intermediate Axemann Limestone is missing Butts (1939, 1945) placed the Nittany-Bellefonte contact midway between the base of the Nittany Dolomite and the top of the Bellefonte Dolomite. However, the writer suggests that the contact should be located at the top of the sandy Etna Furnace Member of the Nittany Dolomite.

FAUNA OF THE NITTANY DOLOMITE

Reports by Previous Workers

Ulrich (1911) reported fossils representing five genera in the Nittany Dolomite at Bellefonte when he assigned the name to the formation. (See

TABLE 4.—*Fossils reported in the Nittany Dolomite by previous workers.*

	ULRICH (1911)	BUTTS AND MOORE (1936)	BUTTS AND OTHERS (1939)	BUTTS (1945)
GASTROPODA	*Ophileta complanata* Whitfield (?Vanuxem)	*Lecanospira* spp.	*Lecanospira*	*Lecanospira*
	Eccyliopterus cf. *E. triangulus* Whitfield	*Ecclliopterus* spp.		
	cf. *Hormotoma artemesia*	*Hormotoma artemesia* (Billings)		
		Orospira sp.		
			Roubidouxia umbilicata Ulrich and Bridge	
BRACHIOPODA	*Syntrophia* cf. *lateralis*	*Syntrophina campbelli* (Walcott)		
ALGAE	*Cryptozoon steeli*	*Cryptozoon steeli*		*Cryptozoon* cf. *C. steeli*

Table 4). He divided the type section of the Nittany Formation into four units of lithologic description; none of these units were recognized by Ulrich southwest from Bellefonte. The lowest of the four units of description, unit 7, is 624 feet thick and contains *Ophileta complanta* Whitfield (? Vanuxem), *Syntrophia* cf. *lateralis* and *Cryptozoon steeli*. In the overlying unit 8, 132 feet thick, he notes the occurrence of slender gastropods that appear to be similar to *Hormotoma artemesia*. No fossils were collected from unit 9, 313 feet thick, but he notes the presence of an *Eccyliopterus* like *E. triangulus* Whitfield in unit 10.

While mapping in the Bellefonte Quadrangle Butts (1936) also measured a section of the Nittany Dolomite in Bellefonte. He reported *Cryptozoon steeli* Seely and several species of *Lecanospira* from the lower part of the formation, and the occurrence of two new species of *Eccyliopterus* and a new species of *Orospira* from the upper part of the Nittany Formation. In addition, Butts also listed two forms that were previously reported by Ulrich, *Syntrophina campbelli* (Walcott) and *Hormotoma artesmesia* (Billings).

Butts mapped the Nittany Dolomite in the Tyrone quadrangle (1939) and in the Hollidaysburg-Huntingdon quadrangles (1945) southwest of the Bellefonte quadrangle. In both of these studies he reported the occurrence of *Lecanospira; Roubidouxia umbilicata* Ulrich and Bridge was reported only in the earlier investigation and cryptozoon chert was collected in the later study only.

Changes in Terminology Used by Previous Workers

In 1926, Butts applied the generic name *Lecanospira* to two species described and illustrated as *Lecanospira (Ophiletta) compacta* and *L. conferta* Ulrich. In the description for *L. conferta,* Butts (1926, p. 94) noted that "this genus has usually been given the name *Ophiletta* but the true *Ophiletta* as determined by Ulrich, is a dextral or right-handed shell as shown in Figures 14-17. Ulrich has named the new genus here shown *Lecanospira*." Knight (1941) presumes that the forms identified by Butts as *Lecanospira (Ophiletta) compacta* were actually *Ophileta compacta* Salter, 1859. Bridge (1930) noted that *Ophileta complanata* has been used as a synonym for *Lecanospira compacta* (Salter) by Whitfield, Miller, Lesley, Grabau and Shimer, Ulrich, and Bassler. Thus, *Ophileta complanata* Whitfield is now *Lecanospira compacta* (Salter).

Syntrophia cf. *lateralis* was reported in the Nittany Dolomite only by Ulrich (1911). In a later study (Ulrich and Cooper, 1938, p. 247) Ulrich notes that this species occurs in the Cassin Limestone at Fort Cassin, Vermont, and that ". . . reports of this species outside of this area have not been authenticated." In this same study Ulrich (1938, p. 218) describes *Syntrophina campbelli* (Walcott) as being ". . . widely cited as

characteristic of the Roubidoux Formation in Missouri, but actually is confined there to the upper part of the underlying Gasconade Formation" (Figure 7). Butts (1941, p. 33), however, provides an illustration of a specimen of this species collected from a pile of chert that also contained specimens of *Lecanospira*.

Both Ulrich (1911) and Butts (1936) reported species of *Eccyliopterus* in the Nittany Dolomite. Knight (1941, p. 107) comments that the genotype for *Eccyliopterus* Remelé, 1888, is ". . . by subsequent designation of Ulrich and Scofield, 1897 (p. 937), *Eccyliomphalus alatus* C. F. Roemer, 1876." This genus was proposed by Portlock (1843, p. 411) and was originally spelled *Ecculiomphalus*. Shimer and Shrock (1944) show *Eccylopterus* Remelé, 1883, to be the equivalent of *Ecculiomphalus* Portlock 1843, and indicate a preference for the earlier usage, *Ecculiomphalus*.

The name *Roubidouxia umbilicata* was applied by Ulrich and Bridge (in Dake and Bridge, 1932) to specimens collected from the Roubidoux Formation in Missouri (see Figure 7). They intended these specimens to be types for both the species and genus. Bridge and Cloud (1947, p. 554), however, noted that the genus *Roubidouxia* was validated by Butts (1926, p. 96) when he reported the occurrence of *Roubidouxia depressa* Butts. Thus, *R. depressa* and not *R. umbilicata* is the genotype upon which the genus is based. "Moreover, study of the holotype of Butts' species reveals that it is not cogeneric with the species *umbilicata,* Ulrich and Bridge, and that a new genus must be erected for the reception of the latter" (Bridge and Cloud, 1947, p. 554). They proposed the genus *Rhombella*. Thus, *Roubidouxia umbilicata* Ulrich and Bridge is now *Rhombella umbilicata* (Ulrich and Bridge).

Collections Obtained in Present Study

It is apparent in the previous section that relatively few fossils have been reported from the Nittany Dolomite. Apparently the belief that dolomites generally contain few fossils, or fossils so poorly preserved that identification is impossible, discouraged workers from adequately searching for fossils in dolomite beds of the Nittany Formation. Most of the fossils previously reported in the Nittany Dolomite are preserved in one of two ways; either the shell has altered to dolomite thereby obliterating its distinctive features, or the original shell material was removed and all that remains of the specimen are internal or external molds. However, there is a third method of preservation in which the original carbonate shell material is replaced by silica. If the surrounding dolomite material is dissolved away by hydrochloric acid the silicified shells are left behind in the insoluble residue. In many silicified specimens even the most delicate structures are perfectly preserved. Nearly all of the fossils collected

in this study, but not previously reported by other workers in the Nittany Dolomite, are preserved in this manner.

To find silicified fossils it is not necessary to indiscriminately dissolve every dolomite sample collected. Dolomites containing silicified fossils have several features in common.

(1) No silicified fossils were found in the insoluble residues of dolomite samples whose weathered surfaces completely lacked any indication of siliceous material. The naturally weathered surface of the dolomite sample should be examined carefully. If the sample contains any silicified material it invariably will be etched in relief.

(2) Although fossils were found most commonly in beds of medium- to dark-grey, medium to coarsely crystalline dolomite, they also occur in beds of light-grey, medium to coarsely crystalline dolomite.

(3) Fossils commonly occur in dolomite beds that contain such granular elements as oolites and pellets, rock fragments, and sand-size quartz grains.

(4) No fossils were found in beds of light-grey, finely crystalline dolomite.

In addition, some of the chert masses found piled along the margins of cultivated fields contain fossils. Although the exact stratigraphic position of the fossil would be unknown, the knowledge that the fossil is present in the area may provide the encouragement needed to locate the fossil in place.

All fossils collected in this study or reported by previous workers in the Nittany Dolomite of central Pennsylvania are listed in Table 5. In addition, the approximate stratigraphic position and method of preservation of fossils collected by the writer are indicated. The locations and stratigraphic positions at which these fossils occur in the sections measured and described in this study are shown in Plate 24.

Distribution of Fossils in the Nittany Dolomite

Nearly all the fossils collected from the Nittany Dolomite in this study occur within the lowermost 600 feet and uppermost 150 to 200 feet of the formation. Fossils are almost entirely lacking in the sequence that is between these fossiliferous intervals.

In this study the Nittany Dolomite is subdivided into three members on the basis of presence versus absence of silt- and sand-size quartz grains in the dolomite beds. The upper limit of the sandy Forge Union Member corresponds closely to the top of the lower fossiliferous sequence, and the middle nonsandy Shoenberger Member and the sparsely fossiliferous interval occupy about the same stratigraphic position. (See Plate 24). The upper sandy Etna Furnace Member nearly corresponds to the upper

Table 5.—*Occurrence, stratigraphic distribution, and method of preservation of fossils collected from the Nittany Dolomite.*

	FAUNA	COLLECTED BY OTHER WORKERS	COLLECTED IN THIS STUDY	APPROXIMATE STRATIGRAPHIC OCCURRENCE			METHOD OF PRESERVATION		
				Forge Union Member	Shoenberger Member	Etna Furnace Member	Silicified	Dolomitized	Molds in Dolomite or Chert
PORIFERA	Oxeakloster sponge spicules		X			X	X		
BRACHIOPODS	*Finkelnburgia* sp.		X			X	X		
	Diparelasma sp.		X			X	X		
	Tritoechia pennsylvanica		X			X	X		
	Syntrophina campbelli	X							
	Diaphelasma pennsylvanicum		X	X			X		
	Syntrophinella cf. *S. cooperi*		X	X			X		
	Syntrophia cf. *lateralis*	X							
GASTROPODS	*Ecculiomphalus* spp.	X							
	Hormotoma artemesia	X							
	Lecanospira compacta		X	X				X	X
	Lecanospira cf. *L. salteri*		X	X				X	
	Lecanospira spp.	X	X	X			X	X	X
	Lytospira sp.		X	X				X	
	Ophileta cf. *O. solida*		X			X		X	
	Ophileta sp.		X	X			X	X	
	Orospira sp.	X	X			X	X		
	Roubidouxia umbilicata	X							
CEPHALOPODS	cf. *Proterocameroceras* sp.		X		X		X		
	cf. *Clitendoceras* sp.		X		X		X		
	cf. *Platysiphon* sp.		X		X		X		
ALGAE	*Cryptozoon steeli*	X	X	X			X		

fossiliferous sequence. However, the lower boundary of the upper fossiliferous sequence falls within the lower part of the Etna Furnace Member. Thus, the limits of the fossiliferous sequences are not exactly the same as the boundaries of the three lithologic members, but they are so very similar that the stratigraphic distribution of fossils in the Nittany Dolomite can be described in terms of their position within lithologic members. This matching of lithologic and fossil sequences is done to simplify the discussion and should not be interpreted as an attempt to equate three rock-stratigraphic units with three biostratigraphic units.

Forge Union Member

The most distinctive fossils found in the Nittany Dolomite are species of *Lecanospira* that occur in the upper 200 feet of the Forge Union Member. This sequence is referred to as the *Lecanospira* Zone of the Nittany Dolomite. Two species, *L. compacta* and *L. salteri,* were recognized, but specimens of this genus commonly are preserved so poorly that only a generic identification is possible. *Diaphelasma pennsylvanicum* and *Syntrophinella* cf. *S. cooperi* are identified in the Nittany Dolomite for the first time. They are restricted to this member and are important elements in correlating the lower part of the Nittany Dolomite with formations in nearby areas. Silicified algal masses resembling *Cryptozoon steeli* are confined to the lower part of the member whereas *Lytospira* and *Ophileta* occur near the top. Both of these gastropod genera occur in the upper part of the underlying Stonehenge Limestone and Larke Dolomite, but only *Ophileta* ranges into higher beds. Unidentifiable fragments of trilobites were found near the middle of the member. The Forge Union Member contains more fossils, both in numbers of species and total abundance, than either of the other two members.

Shoenberger Member

Isolated silicified endoceroid siphuncles were the only fossils collected in the Shoenberger Member. These forms represent three genera, cf. *Platysiphon,* cf. *Clitendoceras* and cf. *Proterocameroceras.*

Etna Furnace Member

Fossils collected from this member include *Tritoechia pennsylvanica, Finkelnburgia* sp., *Diparelasma* sp., *Ophileta* cf. *O. solida, Orospira* sp. and oxeakloster sponge spicules. All of these forms, with the exception of *Orospira* sp., have been reported in the overlying Axemann Limestone. Oxeakloster sponge spicules have been collected from beds located at about the middle of the Bellefonte Dolomite near Union Furnace, Huntingdon County.

CHANGE IN THICKNESS OF THE NITTANY DOLOMITE FROM BELLEFONTE SOUTHWESTWARD TO LUTZVILLE

Variation in Thickness of Members of the Nittany Dolomite

The thickness of each of the three members into which the Nittany Dolomite has been divided varies from Bellefonte southwestward to Lutzville. (See Plate 24). The lower sandy Forge Union Member decreases from 580 feet at Bellefonte to about 350 feet at Spruce Creek and maintains approximately this thickness to Lutzville. The overlying nonsandy Shoenberger Member decreases from 500 feet at Bellefonte to 400 feet at Mount Etna, and continues to decrease to about 300 feet at Waterside and Lutzville. The upper sandy Etna Furnace Member increases from about 130 feet at Bellefonte to 300 feet at Mount Etna, thins to about 200 feet at Waterside, then thickens to more than 300 feet at Lutzville.

The decrease in thickness of the Forge Union Member southwest of Bellefonte is the result of interfingering with nonsandy dolomite beds in the overlying Shoenberger Member. The decrease in thickness of the Shoenberger Member southwest of Shoenberger is the result of interfingering between nonsandy dolomite beds in the upper part of Shoenberger Member and sandy dolomite beds in the overlying Etna Furnace Member.

Change in Thickness of the Nittany Dolomite

As shown in the generalized stratigraphic cross section (Plate 24), the Nittany Dolomite is somewhat wedge-shaped as it thins from about 1,200 feet at Bellefonte to 820 feet at Waterside and 1,050 feet at Lutzville. The Nittany Dolomite at Lutzville, however, may be up to 100 feet thinner than indicated because the Nittany Dolomite-Larke Dolomite contact occurs within a concealed interval and was located somewhat arbitrarily.

When Ulrich (1911) named the Nittany Dolomite he expressed the opinion that ". . . southwest from Bellefonte the Stonehenge, and at least a large part, if not the whole, of the Nittany Dolomite wedges out . . ." (p. 660).

Two forms, *Lecanospira* and *Cryptozoon steeli,* occur in the lower half of the Nittany Dolomite at Bellefonte. Specimens of *Lecanospira* also were collected from dolomite beds at the Mount Etna, Williamsburg, Waterside and Lutzville sections. Butts (1939) reports the occurrence of *Cryptozoon steeli* in the Nittany Dolomite of the Tyrone quadrangle, and the writer found excellent specimens of this fossil in the lower part of the Nittany Formation at Lutzville. Thus, paleontological evidence indicates that the Nittany Dolomite does not disappear southwestward from Bellefonte.

It is difficult to explain the overall thinning of the Nittany Dolomite by changes in the thickness of each of the three members, for at most sections when one member thins the overlying member thickens. (See Plate 24). Ulrich (1911) suggested that the Nittany Dolomite may thin to the south by overlap. There is evidence suggesting that his explanation is possible. Southwest from Bellefonte the Stonehenge Limestone changes to the Larke Dolomite, but fossils that occur in the *Bellefontia* Zone at the top of the Stonehenge persist into and near the top of the Larke. The *Lecanospira* Zone occurs 400 to 600 feet above the Stonehenge Limestone at Bellefonte, and specimens of this genus were found about 300 feet above the Larke Dolomite at Mount Etna, from 200 to 300 feet above the Larke at Williamsburg and Waterside, and about 400 feet above the Larke at Lutzville. Thus, these two zones persist throughout the area of investigation. Southwest from Bellefonte the lowest occurrence of *Lecanospira* systematically approaches the Nittany Dolomite-Stonehenge Limestone or Nittany Dolomite-Larke Dolomite contact. In the event that the dolomite sequence that makes up the *Lecanospira* Zone was deposited at the same time, and the interbedded limestone and dolomite sequence of the underlying *Bellefontia* Zone was deposited at the same time, then the thinning of the Nittany Dolomite can be accounted for by the decrease in section between these two zones. The variation in thickness, therefore, is probably the result of either a relatively faster rate of accumulation in central Centre County or of short periods of nondeposition in north and central Bedford County, or some combination of these.

CORRELATION

INTRODUCTION

The fauna of the Nittany Dolomite provide evidence needed to establish correlations with formations of similar age in the following nearby regions of the eastern United States: Washington County, Maryland; Chambersburg, Franklin County, Pennsylvania; West-central Vermont; Berks County, southeastern Pennsylvania; Valley and Ridge Province, Virginia; Valley and Ridge Province, West Virginia. The tentative correlations established between the Nittany Dolomite and stratigraphically adjacent units in central Pennsylvania and formations exposed in these regions are shown in Figure 6. Since meager faunal assemblages have been reported from some of the formations in a few of these localities, improved correlations will require the discovery of fossils in those sequences from which none have been reported. In general, the lithologic nature of most of the Lower Ordovician formations exposed in the eastern United

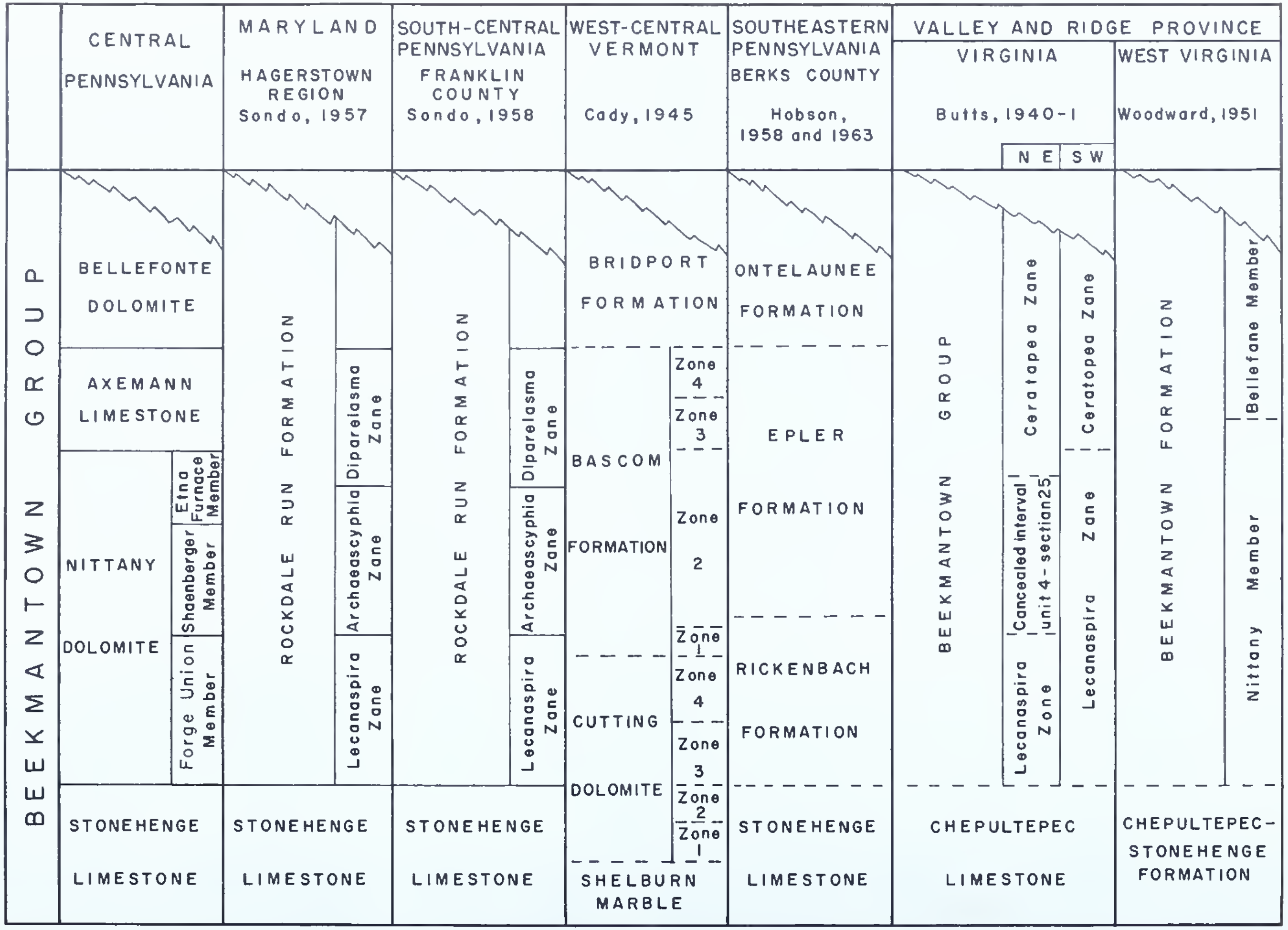

Figure 6. Tentative correlation of Lower Ordovician Nittany Dolomite and stratigraphically adjacent formations with units in nearby regions of the eastern United States. Only the central Pennsylvania section is drawn to scale. Dashed line indicates position of boundary in central Pennsylvania is uncertain.

States is adequately described. Thus, lithologic similarities between the Nittany Dolomite and the correlated formations are also considered.

The correlation established by Twenhofel and others between the Lower Ordovician sections of southeastern Missouri and central Pennsylvania is briefly described.

CORRELATION WITH LOWER ORDOVICIAN SECTIONS IN EASTERN UNITED STATES

Washington County, Maryland

Sando (1957) made a detailed study of the Beekmantown Group in Maryland. His area of investigation was the northern extension of the Great Valley of Virginia into Washington County, Maryland. Sando subdivided the Beekmantown into three formations, the Stonehenge Limestone, Rockdale Run Formation and Pinesburg Station Dolomite, and elevated the Beekmantown to group status.

The upper part of the Stonehenge Limestone contains many of the fossils reported by Donaldson (1959) from the *Bellefontia* Zone of the Stonehenge Limestone in Bellefonte. The Stonehenge in Maryland is correlated by Sando with the Stonehenge Limestone of central Pennsylvania.

The overlying Rockdale Run Formation is from 2,400 to 2,600 feet thick. The upper one-third is composed of dolomites and mottled dolomitic limestones, whereas the lower two-thirds consists of silty mechanical limestones and algal limestones and contains only subordinate amounts of dolomite. Some limestones and dolomites in the lower half of the formation contain minor amounts of sand. Sando noted the presence of three lithologic zones in the Rockdale Run. The lowest, a zone of cryptozoon chert, is confined to the lower 100 to 200 feet of the formation. Two hundred feet above the chert zone there is a 100- to 200-foot-thick zone in which oolitic limestones are abundant. The prolific *Lecanospira* fauna occur within this zone and are nearly confined to these beds. The uppermost zone, or dolomite member, is 200 to 600 feet thick and its base ranges from 800 to 1,000 feet above the *Lecanospira* Zone. It is composed of cherty, mottled and laminated dolomites that grade laterally and vertically into an interbedded sequence of dolomites and mottled dolomitic limestones.

Sando established four faunal zones in the Rockdale Run Formation. The lower zone, 200 to 560 feet above the base, is named for the gastropod *Lecanospira* which is confined to this interval. Important genera also confined to this zone include *Diaphelasma, Syntrophinella, Ecculiomphalus, Macluritella* and cf. *Ophileta*. *Finkelnburgia* ranges into higher beds. Sando lists the following as the most important species of the

Lecanospira Zone: *Finkelnburgia virginica, Diaphelasma pennsylvanicum, Syntrophinella acutisulcata, S. cooperi, Lecanospira compacta?,* cf. *L. salteri* and *Macluritella marylandica.*

Lecanospira and *Diparelasma pennsylvanicum,* a critical element in the *Lecanospira* Zone of Maryland, West Virginia, Texas, Oklahoma and central Pennsylvania, occur in the Forge Union Member of the Nittany Dolomite. *Ecculiomphalus* and *Ophileta* were collected from beds near the top of the *Lecanospira* Zone at Bellefonte, but *Ophileta* ranges into the Axemann Limestone. Thus, the Forge Union Member, about 600 feet thick at Bellefonte, is correlated with the Maryland sequence that ranges from the base of the Rockdale Run Formation to the top of the *Lecanospira* Zone.

The *Lecanospira* Zone of the Rockdale Run Formation consists of limestones interbedded with some dolomites, whereas the Forge Union Member is composed entirely of dolomite. However, there are three lithologic features common to both intervals. First, a zone of cryptozoon chert is developed between 100 and 200 feet above the base of the Nittany Dolomite at Lutzville. Bedded and nodular chert, in general, occurs most abundantly in and below the *Lecanospira* Zone. Second, sand- and silt-size quartz grains occur in many dolomites in the lower half of the Nittiny Dolomite. Third, oolitic dolomites occur throughout the lower half of the Nittany Dolomite but were observed most commonly in the upper 200 feet of the Forge Union Member, the zone of *Lecanospira.*

The *Lecanospira* Zone in Maryland is overlain by the *Archaeoscyphia* Zone. This zone ranges from 560 to 790 feet above the base of the Rockdale Run Formation. None of the three species described by Sando as important elements of this zone were found in the Nittany Dolomite. However, Sando lists 11 genera and 14 species of cephalopod siphuncles from this zone. Among these *Clitendoceras* and *Proterocameroceras* occur in beds below, in, and above the zone, whereas *Platysiphon* ranges into this zone from below. Two gastropod genera, *Ceratopea* and *Diparelasma,* occur in the uppermost beds of the zone, but they are considerably more abundant in the overlying *Diparelasma* Zone.

Silicified siphuncles identified as cf. *Platysiphon,* cf. *Clitendoceras* and cf. *Proterocameroceras* were the only fossils found in the Nittany Dolomite by the writer from the sequence that begins above the highest occurrence of *Lecanospira* and extends vertically for 400 to 600 feet. This sparsely fossiliferous interval in the Nittany Dolomite corresponds closely to the Shoenberger Member, and is correlated with the *Archaeoscyphia* Zone in Maryland.

Sando's *Diparelasma* Zone, named for the brachiopod, extends from 790 to 1,420 feet above the base of the Rockdale Run Formation. Three species of *Tritoechia* occur in this zone, and *Orospira* occurs only within

this interval. *Finkelnburgia* and *Ceratopea* range into beds above this zone.

The writer collected specimens of *Diparelasma* sp., *Finkelnburgia* sp., and *Ophileta* cf. *O. solida* from a sequence of dolomites in the Nittany Formation extending downward 200 feet below the base of the Axemann Limestone at the Mount Etna section. In addition, *Tritoechia pennsylvanica* and *Orospira* sp. were collected at the base of an interval of sandy dolomites near the top of the Nittany Formation at Shoenberger, but their position with respect to the Axemann Limestone is uncertain because limestones in the Axemann are missing. All of these fossils occur within the 150 to 300 foot thick sequence of sandy dolomites comprising the Etna Furnace Member of the Nittany Dolomite.

Lacking information on the occurrence of fossils in the upper part of the Nittany Dolomite, Sando correlated the entire *Diparelasma* Zone of Maryland with the Axemann Limestone in central Pennsylvania. However, on the basis of fossils collected in this study the uppermost 200 feet of the Nittany Dolomite are thought to be equivalent to the lower part of the *Diparelasma* Zone.

Chambersburg, Franklin County, Pennsylvania

Sando (1958) examined the Lower Ordovician section exposed near Chambersburg after completing the study of the Beekmantown Group in nearby Washington County, Maryland. Stose (1908, 1909) previously described the section at Chambersburg and listed fossils identified by Ulrich from rocks within this region. The stratigraphy of this area, and of the adjacent area in Maryland, was later described by Ulrich (1911). Since then the Chambersburg section has served as the reference section for Lower Ordovician stratigraphy in the Great Valley of southern Pennsylvania and Maryland.

Sando (1958) notes lithologic and faunal similarities between the sections exposed in Maryland and Chambersburg. In the Chambersburg area he lowered the base of the Stonehenge Limestone, and assigned the remaining portion of the Beekmantown Group to the Rockdale Run Formation. The Rockdale Run Formation in this region is about 2,550 feet thick and consists of interbedded limestones and dolomites. According to Sando (1958, p. 841) "algal and mechanical limestones dominate the lower two-thirds of the formation; dolomites and dolomitic limestones are abundant in the upper third."

The faunal zones established by Sando (1957) for the Rockdale Run Formation in Maryland are equally well developed in the formation at Chambersburg. None of the additional fossils collected by Sando at Chambersburg were found by the writer in the Nittany Dolomite. Thus, the correlation established between the Nittany Dolomite and the Rockdale

Run Formation in the Chambersburg area is the same as the correlation with the Rockdale Run Formation in Washington County, Maryland.

West-central Vermont

Cady (1945) subdivided rocks in the Beekmantown Group of west-central Vermont into four mappable units. These formations, the Shelburn Marble, Cutting Dolomite, Bascom Formation and Bridport Dolomite, nearly correspond to divisions B, C, D and E previously established by Brainerd and Seely (1890) in the section exposed at Shoreham, Vermont.

The Shelburn Marble, 300 to 600 feet thick, is composed of light-colored marble. Few fossils have been reported from the Shelburn Marble, but those found indicate that the age of the formation is earliest Ordovician.

The overlying Cutting Dolomite, about 350 feet thick, is described by Brainerd and Seely (1890) as composed of magnesian limestones. Dolomites at the base and near the middle also contain sand in sufficiently large quantities to be called calciferous or dolomitic sandstones. Fossils reported in the Cutting include the worm boring "*Scolithus*" in zone 1 at the base of the formation, and *Ophileta complanata* and *Lecanospira compacta* above the cross-bedded sandstones in zone 1 (Wheeler, 1941).

The Bascom Formation, 375 feet thick, is an interbedded sequence of limestones and dolomites with minor amounts of sandstone, quartzite, limestone breccia and sandy calcareous shale, and is distinguished by its lithologic complexity. Although quartz grains occur throughout the Bascom Formation they appear to be concentrated in beds located near the base and middle of the unit. Cady (1945) describes the occurrence of numerous gastropods and straight-shelled cephalopods in zones 1 and 4 of the Bascom Formation. *Lecanospira (Ophileta) compacta* is reported in zone 1 by Wing (in Dana, 1877) and Brainerd and Seely (1890). According to Cady (1945), *Isoteloides whitfieldi* Raymond, *Hystricurus conicus* (Billings), *Maclurites matutinus* (Hall), *M. cordidus* (Hall), *M. affinis* (Billings) are reported from zones 3 and 4.

The Bridport Dolomite is about 470 feet thick. Brainerd and Seely (1890) describe the unit as being composed of light-colored, fine-grained, magnesian limestones that occur in beds one to two feet thick. Few fossils have been found in the Bridport. However, some of the important forms reported include *Bucania tripla* Whitfield, *Turritospira confusa* (Whitfield), and *Isochilina seelyi* (Whitfield).

Ophileta complanata was reported by Donaldson (1959) in the Stonehenge Limestone in central Pennsylvania, and it occurs in beds above zone 1 of the Cutting Dolomite. *Lecanospira* occurs in the upper 200 feet of the Forge Union Member of the Nittany Dolomite in central Pennsyl-

vania, and ranges from the top of zone 1 in the Cutting Dolomite to the top of zone 1 in the Bascom Formation, a thickness of 370 feet. The Shelburn Marble and zones 1 and 2 in the Cutting are correlated with the Stonehenge Limestone. The interval containing the *Lecanospira* fauna, zones 3 and 4 of the Cutting and zone 1 of the Bascom, is compared to the Forge Union Member of the Nittany Dolomite. Calciferous and dolomitic sandstones in zone 3 of the Cutting Dolomite correspond in lithology and position to sandy dolomites in the Forge Union Member.

No fossils were reported in zone 2 of the Bascom Formation, but the faunal assemblages in zones 3 and 4 contain many of the forms reported by Butts (in Butts and Moore, 1936), Macaulay (1952), and Lees (1964) from the Axemann Limestone. Fossils common to both formations include *Isoteloides, Hystricurus* and *Maclurites affinis,* an especially critical element in establishing a correlation between these two regions. Thus, the rest of the Nittany Dolomite above the Forge Union Member is questionably correlated with zone 2 in the Bascom Formation. Zones 3 and 4 in the Bascom Formation appear to be equivalent to the Axemann Limestone.

Berks County, Southeastern Pennsylvania

Hobson (1958, 1963) studied the Lower Ordovician Beekmantown section in central Berks County, Pennsylvania. He divided the Beekmantown into four mappable units. The name for the lowest unit, the Stonehenge Limestone, was previously applied by Stose to a sequence of limestones exposed near Chambersburg, Franklin County, Pennsylvania. Its use by Hobson represents an extension of the term into the area. The overlying units, the Rickenbach, Epler and Ontelaunee Formations, were named by Hobson (1958).

Hobson collected fossils from throughout the section, but most forms occurred within two zones. The lower zone occurs in the upper 60 feet of the Stonehenge Limestone, 250 feet thick in Berks County, and contains the following forms; *Nanorthis?* sp., *Finkelnburgia* sp., brachiopod shells, hystricurid trilobites and pelmatozoan plates. The Stonehenge Limestone in Berks County is tentatively correlated with the Stonehenge Limestone in central Pennsylvania.

The overlying Rickenbach Formation is about 560 feet thick in Berks County and consists of light- to medium-grey, finely to coarsely crystalline dolomites. Hobson divides the Rickenbach into a lower member, about 210 feet thick, and an upper member, about 350 feet thick. A 30-foot interval of dolomite interbedded with dark chert occurs near the base of the upper member, and a sequence of sandy dolomites 90 to 110 feet thick occurs 60 feet above the chert zone. Hobson found no fossils in the upper member, but he collected low-spired gastropods, specimens with

structures resembling cryptozoon, and a single orthocerid chepalopod in the lower member.

The Epler Formation is about 800 feet thick in Berks County and is composed of medium- to medium-light-grey limestones interbedded with finely crystalline dolomites. Most fossils found by Hobson in this unit occur in the upper fossiliferous zone, a 60-foot-thick limestone sequence located about 200 feet below the top of the formation. From this zone he reports *Ophileta?* sp., *Raphistoma* sp., diparelasmid brachiopods, ostracods and bathyurid trilobites. Hobson also found *Finkelnburgia* sp., diparelasmid brachiopods and structures resembling cryptozoon in the lower Epler.

The Ontelaunee Formation is from 600 to 700 feet thick in Berks County. A 160-foot-thick sequence of finely to medium crystalline dolomite interbedded with dark chert occurs near the base. The rest of the formation consists of finely crystalline dolomites with some limestone interbeds near the top. The few fossils collected by Hobson, low-spired dolomitized gastropod shells, a high-spired gastropod similar in appearance to *Hormotoma,* and a single orthocerid cephalopod, occur in thin limestone beds in the upper part of the formation.

The Nittany Dolomite is tentatively correlated with the Rickenbach Formation and that part of the Epler Formation underlying the 60-foot-thick fossiliferous sequence. The position of chert and sandy dolomite beds in the upper half of the Rickenbach compares favorably with similar lithologies in the upper part of the Forge Union Member. Specimens of *Lecanospira* have not been collected in Berks County, but the meager faunal assemblage reported in the Rickenbach Formation resembles, in a very general way, the assemblage found in the Forge Union Member of the Nittany. Dolomites in the Epler Formation below the fossiliferous limestones contain forms similar to fossils identified in the Shoenberger and Etna Furnace Members of the Nittany Dolomite.

The 60-foot sequence of fossiliferous limestones and the remainder of the Epler Formation are correlated with the Axemann Limestone.

Knowles (1964) reports the occurrence of a chert zone near the base of the Bellefonte Dolomite in Friends Cove, Bedford County. This chert persists throughout the region and is used as a guide in locating the Bellefonte Dolomite-Axemann Limestone boundary, especially in areas where limestones of the Axemann are missing. The thick chert zone near the base of the Ontelaunee in Berks County may occur at approximately the same position as the chert zone in the Bellefonte Dolomite. The Ontelaunee is tentatively correlated with the Bellefonte Dolomite.

Valley and Ridge Province, Virginia

The Lower Ordovician rocks exposed in the Valley and Ridge Province of the Appalachian Valley, Virginia, were described by Butts (1940,

1941). These rocks are exposed along a curved belt 50 miles wide that extends from the northeast border to the southwest border of the state and adjoins West Virginia to the west for most of its length. The Lower Ordovician sequence consists of two units, the lower Chepultepec Limestone and upper Beekmantown Group.

The Chepultepec Limestone ranges from 36 to 600 feet thick and consists of pure limestones with some interbeds of magnesian limestone. Some of the fossils reported from this unit are *Gasconadia putilla, Helicotoma uniangulata* and *Ophileta complanata.* On the basis of faunal similarity the Chepultepec Limestone is tentatively correlated with the Stonehenge Limestone in central Pennsylvania.

The Beekmantown Group is characterized by three lithologic facies in Virginia. In the northeastern portion of the province the Beekmantown is composed of limestones with some interbeds of dolomite, whereas the southwestern half consists of dolomites with few limestone interbeds. Between these two regions the Beekmantown consists of about equal amounts of limestone and dolomite. The Beekmantown thins from about 3,100 feet in the northeastern part of the belt to about 1,200 feet at the southwestern border of Virginia.

Butts divides the Beekmantown of northeastern Virginia into two units, a lower *Lecanospira* Zone, 1,350 feet thick, and an upper *Ceratopea* Zone. The *Lecanospira* Zone is distinguished by several species of *Lecanospira* and *Roubidouxia,* and also contains specimens of *Finkelnburgia, Syntrophina, Ophileta, Hormotoma* and *Eccyliopterus.* The *Ceratopea* Zone contains, in addition to several species of this genus, *Orospira, Ophileta* including *O. solida* Butts, *Hormotoma,* and *Maclurites* including *M. affinis* (Billings).

The *Lecanospira* Zone in Virginia is considerably thicker than the *Lecanospira* faunal Zone established by Sando (1957) in Maryland and by the writer in central Pennsylvania. Nevertheless, the interval between the base of the Nittany Dolomite and the highest occurrence of *Lecanospira,* essentially the Forge Union Member, is tentatively correlated with the *Lecanospira* Zone of the Beekmantown Group in northeastern Virginia. The rest of the Nittany Dolomite is correlated questionably with the concealed interval, unit 4 of section 25 (Butts, 1940), between the *Lecanospira* and *Ceratopea* Zones. The Axemann Limestone is correlated with unit 5 of section 25 (Butts, 1940) in the lower third of the *Ceratopea* Zone.

In southwestern Virginia *Lecanospira* and *Roubidouxia* occur in a 162-foot-thick zone about 300 feet below the top of the Beekmantown Group. Butts assigned the lower 1,000 feet to the *Lecanospira* Zone and the upper 200 feet to the *Ceratopea* Zone. The Nittany Dolomite is tentatively correlated with the *Lecanospira* Zone in southwestern Virginia. The Axe-

mann Limestone and Bellefonte Dolomite, a sequence consisting of about 2,000 feet of section, are tentatively correlated with the *Ceratopea* Zone in southwestern Virginia. The question whether each formation recognized in the Beekmantown Group of central Pennsylvania is represented in southwestern Virginia, or proportionally thinned, or entirely missing, can be answered only after the Lower Ordovician section in southwestern Virginia has been studied in greater detail.

Valley and Ridge Province, West Virginia

Outcrops of Lower Ordovician rocks in West Virginia are confined to four narrow and discontinuous belts along the eastern margin of the state. Three of these areas are in the northeastern "Panhandle" region; the other area is near the most sourthern part of the state in Mercer and Monroe Counties. All belts occur along the western margin of the Valley and Ridge Province, and the rocks exposed in them are lithologically and faunally similar to Lower Ordovician rocks exposed to the east and south in Virginia.

Woodward (1951) separates the Lower Ordovician sequence, or Canadian Series, into a lower Chepultepec-Stonehenge Formation and upper Beekmantown Formation. He recognizes two members in the Beekmantown, the lower Nittany and upper Bellefonte.

The Chepultepec-Stonehenge Formation ranges up to 500 feet in thickness, and is correlated by Woodward with the Stonehenge Limestone in central Pennsylvania.

The Beekmantown Formation ranges from 2,500 to 3,000 feet in thickness in the northeastern belt. The Nittany Member is from 700 to 1,000 feet thick and consists of blue-grey to dark-grey, relatively pure limestones. Less than 10 percent of the member is composed of dolomite, and chert is sparse. The Bellefonte Member ranges from 1,000 to 1,500 feet in thickness and is lithologically more complex than the Nittany Member. It contains approximately equal amounts of limestone and dolomite, but the dolomite beds are concentrated in the upper part of the member. No units in the Beekmantown contain sand in any appreciable quantity. The only fossils reported are *Cryptozoon* in the Nittany Member and scattered occurrences of *Ceratopea* in the Bellefonte Member.

The Beekmantown thins to 1,250 feet in the southeastern belt, and dolomites predominate over limestones by a ratio of about 2 to 1. The Nittany Member is from 700 to 750 feet thick and consists of grey, finely crystalline massive dolomite. Residual chert is fairly abundant in the soil overlying rocks of this member. The Bellefonte Member has thinned to between 300 and 400 feet and consists of dolomite beds with some limestone interbeds, especially near the top. No *Ceratopea* were collected from the Bellefonte Member in this region.

Woodward (1951) lists essentially the same faunal assemblage for the Nittany and Bellefonte Members as Butts (1940) reported for the Beekmantown Group in Virginia, but few of these forms are listed in any of the section descriptions provided. Correlation with the sequence exposed in West Virginia will require additional paleontological data. However, in a general way, the Nittany Dolomite in central Pennsylvania can be compared to most of the Nittany Member, the Axemann Limestone to the uppermost Nittany Member and lowermost Bellefonte Member, and the Bellefonte Dolomite to the rest of the Bellefonte Member.

The Nittany and Bellefonte Members in West Virginia compare favorably with the *Lecanospira* and *Ceratopea* Zones established by Butts in the Beekmantown Group of Virginia. In both states the Beekmantown sequence thins and becomes more dolomitic to the southwest.

CORRELATION WITH SOUTHEASTERN MISSOURI SECTION

In the previous chapter references were made to several fossils that occur in two formations that are part of the Lower Ordovician section in Missouri. The generic names for these fossils are taken from the name of the formation in which they occur. These formations also serve as representative formations for the Canadian Series in the correlation chart for the Ordovician System in North America. In order to show the relative age relationship between Lower Ordovician formations exposed in southeastern Missouri and central Pennsylvania the correlation established by Twenhofel (in Twenhofel and others, 1954) is shown as Figure 7.

SEDIMENTATION

INTRODUCTION

In previous chapters of this report dolomites in the Nittany Formation were described in terms of their composition, texture and sedimentary structure. On the basis of dolomite crystal size and sedimentary structure, the dolomites were grouped into ten lithotypes and five sublithotypes, and the distribution of the lithotypes in the Nittany Formation, based on their occurrence in the 12 sections measured, was described.

The discussion to follow is principally concerned with interpretations of the environments in which sediments comprising the Nittany Dolomite were deposited. Different environments unquestionably produced variations in the manner of formation, accumulation and alteration of the original carbonate sediment. Thus, dolomites of the various lithotypes in the Nittany Formation, each with their own characteristics, are believed to reflect environmental conditions of changing types. In consequence, environmental interpretations are advanced on the basis of data obtained

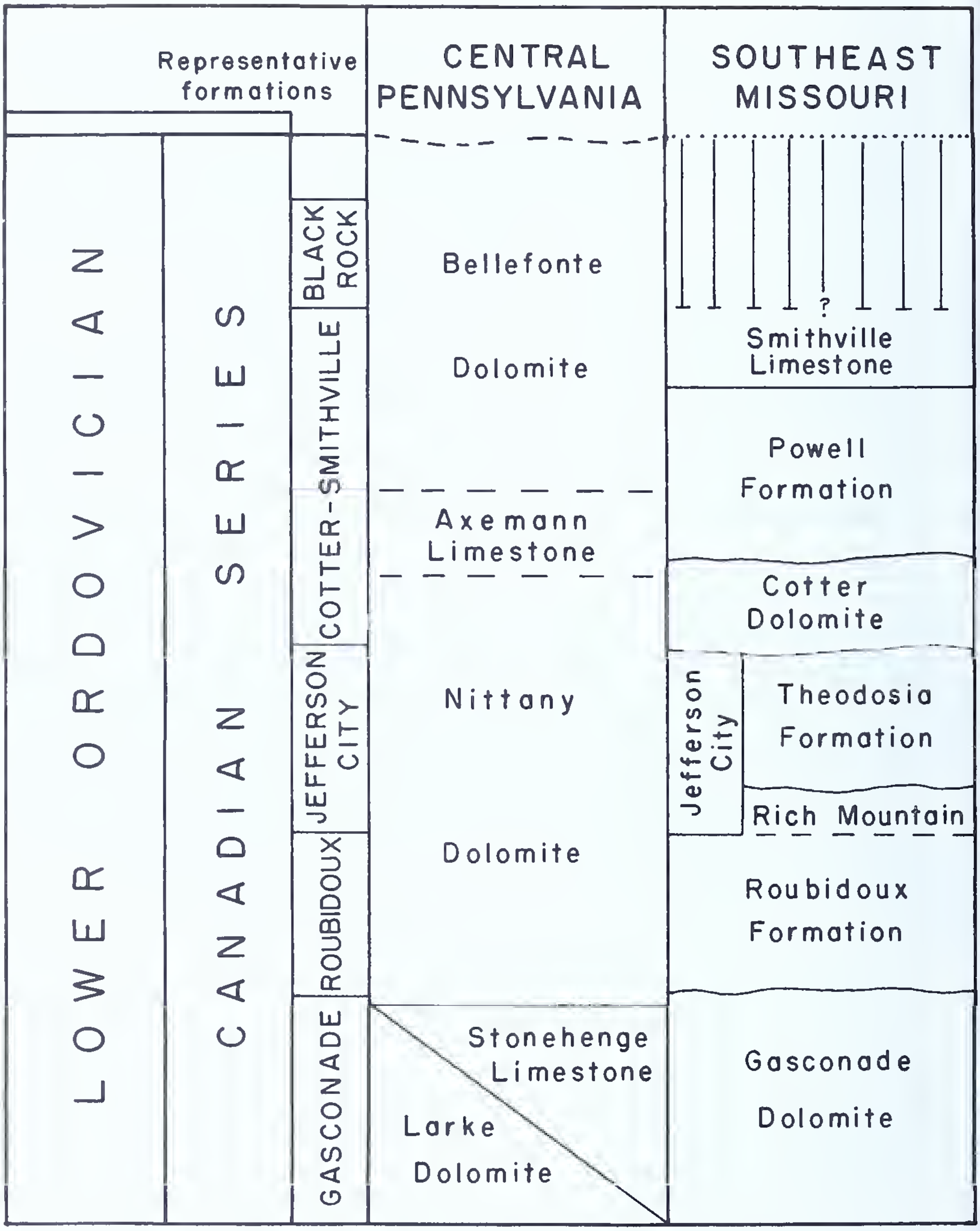

Figure 7. Correlation between Lower Ordovician formations exposed in southeastern Missouri and central Pennsylvania (after Twenhofel and others, 1954).

from examination of hand specimens, acid-etched sections, thin sections and insoluble residues of dolomites. In addition, the cyclic development of rocks representing the various dolomite lithotypes within the Nittany Formation and the apparent restriction of fossils to dolomites of certain lithotypes are important features influencing environmental interpretations.

Many if not all dolomites of the Nittany Formation have altered compositionally and texturally since the time of their accumulation. These

changes have tended to obscure, and in many samples possibly have totally obliterated the original textural features of the rock, and for this reason interpretations of the environmental conditions that existed during and after the time the sediment was accumulating are somewhat speculative.

In the following discussion attention is given to the nature of and probable influence of various environments on the composition, texture and accumulation of the original carbonate sediment, the development of sedimentary structures, and the alteration of the original calcitic sediments to dolomite. Finally, the paleography of central Pennsylvania during the deposition of the Nittany Dolomite is considered.

HISTORY OF SEDIMENTATION

Composition and Texture of Original Carbonate Sediment

Approximately 10 to 15 percent of the studied dolomite samples in the Nittany Formation contain granular components that appear similar to particles composed of calcium carbonate that are forming in the oceans at the present time. For example, gastropod shells that occur in several beds of dark-grey, coarsely crystalline, oolitic dolomite are replaced by coarsely crystalline xenomorphic dolomite. Gastropods living in the oceans today form shells composed of calcium carbonate. Modern gastropod shells examined by Chave (1954) contained less than three percent magnesium carbonate; none of these shells could be described as composed of dolomite. Particles identified on the basis of their shape as pelmatozoan plates were observed in several dolomite samples. Pelmatozoan plates in limestones are characteristically composed of a single calcite crystal. Although most of the plates examined in dolomite samples occur as single crystals of dolomite, many have been texturally altered and parts near the margin of many plates are composed of numerous smaller dolomite crystals. Outlines and, in some instances, concentric structures of oolites are preserved in an interlocking network of dolomite crystals. Oolites forming in the oceans at the present time are composed of very thin layers of calcium carbonate, and these layers impart the concentric structure to the oolite. However, dolomite crystals in oolites in Nittany examples cut across the original concentric structure and commonly extend into some of the adjacent interstitial carbonate material. Particles similar in appearance to tiny, suboval, structureless masses of lime mud that are found in many limestones and that are referred to as pellets occur in several samples of dolomite from the Nittany Formation. Each suboval mass presumably was deposited originally as a separate particle, but in many instances dolomite crystals in pelletic dolomites include two pellets, or the margin of a crystal

in a few cases passes through a pellet. Finally, carbonate rock fragments containing one or more of the components just described were observed in several dolomite samples from the Nittany.

The carbonate of sediments presently being formed in the oceans consists of calcium carbonate, and the above listed components are common features, at least in deposits of shallow-water, nonreef phases. Thus, the fossils, oolites, pellets, and carbonate rock fragments containing any of these particles, that occur in dolomite samples from the Nittany Formation are believed to have been originally deposited as calcium carbonate, and they have altered both compositionally and texturally to dolomite.

Samples of finely crystalline dolomite from the Nittany Formation lack any indication of the preservation of oolites, pellets, rock fragments, fossils, or the debris from these particles. Instead, they consist entirely of an interlocking network of tiny xenomorphic to hypidiomorphic dolomite crystals. The original fine-grained sediment in these dolomites probably was moved along the surface of sedimentation, but any evidence of abrasion may have been destroyed by subsequent recrystallization and dolomitization. However, the uniformity of the dolomite crystal size suggests that the original carbonate sediment was well sorted and thus was acted upon by currents directly above the surface of sedimentation.

Although positive evidence is lacking, it seems possible that finely crystalline dolomites were originally composed of fine-grained calcitic sediments, such as lime muds or silts, that have altered compositionally and texturally. The dolomitization processes modifying the original carbonate sediment probably maintain the size of the original particles but obliterate their original shape.

Krynine (1960), in contrast, has suggested that the crystals of finely crystalline dolomite in light-grey, finely crystalline, laminated dolomites of the Nittany Formation originate as a direct precipitate of dolomite. He argues that the light color indicates an absence of organic material and results from a supersaline environment unfavorable to the development of marine organisms. The supersaline waters developed in broad, shallow basins that are isolated by barriers from areas having a more normal marine environment. Periodically, the barriers are broken and the restricted basins are recharged by normal marine waters. Sediments deposited within the shallow basins are periodically disturbed, and the suspended material settles to the bottom forming layers that are expressed in the rock as laminae.

In summary, the writer suggests that finely crystalline dolomites were originally composed of very fine-grained to fine-grained calcium carbonate. Relatively large granular particles such as oolites, pellets and fossils, or smaller granular particles such as the debris from these grains, were not observed in finely crystalline dolomites in the Nittany. However, dolo-

mitization and recrystallization may have destroyed any original granular texture of the rock. The composition of the original carbonate sediment of finely crystalline dolomites remains subject to question.

Accumulation of Sediments

As previously noted, many of the examined samples of medium-coarsely crystalline dolomite from the Nittany Formation contained oolites, pellets and fossils. Most samples contained only one of these varieties, but several dolomite samples contained all three types. Since these particles do not appear to be badly broken or abraded, an outline that might be produced by movement along the ocean floor, the area in which they accumulated would be close to the area in which they formed.

The fossils found in the Nittany Formation were bottom-dwelling forms that probably lived on a broad shelf covered by shallow, moderately agitated sea water. This sea water was able to maintain a composition favorable to these animals through unrestricted circulation with the deeper open ocean.

Closer to shore, in more agitated waters, layers of calcium carbonate would be deposited on grains that were being moved back and forth by currents, and thus form oolites. Pellets may have been extruded by organisms that reworked the finer sediment on the sea floor, or they may simply be small rounded lumps of fine-grained material. In either case, bottom currents acted to concentrate the pellets with larger particles. The rock fragments that commonly contain oolites, pellets or rock fragments have been moved about and were developed by the breaking apart of recently deposited sediment.

Some very fine-grained sediment may develop in this open and active area, but most of the finer material is carried away by currents to more restricted regions. The sea water apparently was not loaded with abundant suspended material since this material would hinder the growth of many bottom-dwelling organisms. The lack of finer material is further indicated by the nature of the interstitial carbonate material that binds oolites and pellets together into a rock. This interstitial material commonly is composed of clear, coarsely crystalline, xenomorphic or hypidiomorphic dolomite crystals. The absence of any recognizable relict texture in the clear crystals suggests that they formed by the dolomitization of interstitial carbonate cement and not matrix material composed of finer grained sediment.

Finely crystalline dolomites in the Nittany Formation lack oolites, pellets and fossils. Although conclusive evidence concerning the nature of the original carbonate sediment is lacking, this material probably was made up of lime mud or abrasional silt-size debris. This material most likely also developed in shallow sea water. Finely crystalline dolomites com-

monly contain from 10 to 25 percent insoluble material in the form of silt- and sand-size quartz grains and clay. Apparently the quartz grains and clay material are mixed with the finer carbonate sediment, and together they are carried into more restricted quieter areas that are separated from the more active open sea by some type of barrier. The finer sediments also may accumulate within irregularities of the shore line.

The carbonate sediments, including both the very fine-grained material and the larger oolites and pellets, are believed to have formed in shallow, freely circulating sea water. The finer carbonate material is moved out of the area in which it formed, is mixed with detrital material derived from an eroding land mass, and this mixture becomes trapped in near-shore restricted regions. In contrast to this, the coarser carbonate material tends to accumulate in or close to the region in which it formed. These different size sediments accumulate at the same time in separated areas, and in time they become rocks representing different lithotypes. A raising or lowering of the surface of sedimentation would produce a shift in the position of the shoreline and a change in water depth in the near-shore region. Thus, fine-grained carbonate sediment might accumulate in an area where coarse-grained material was previously accumulating. Periodic changes in the position of the shoreline would produce a lateral shifting of environments. The vertical sequence of sediments resulting from such changes would be made up of an alternating succession of fine- and coarse-grained material, and the resulting rock sequence would be an interbedded succession of finely, medium and coarsely crystalline dolomite. The Nittany Dolomite is composed of alternating beds of finely, medium and coarsely crystalline dolomite that may have accumulated under conditions similar to those described above.

Development of Sedimentary Structures

The laminae, streaks and mottling that are prominent on many dolomite samples from the Nittany Formation (see Plate 8) suggest probable conditions that might have occurred during and shortly after the accumulation of the original carbonate sediment. These structures commonly are concentrations of silt- and sand-size quartz grains, clay minerals, interstitial chert or pyrite (see Plate 8, Figures 2, 4 and 6), but in a few samples they are expressed as differences in dolomite crystal size (Plate 8, Figure 3). The quartz grains and clay material were derived from an eroding land mass and transported into the region of carbonate accumulation. Thus, the occurrence and shape of these sedimentary structures was controlled in part by the amount and type of detrital material supplied to the sea, the strength and duration of distributing currents, and the details of compaction and slumpage after accumulation.

Laminae in most finely crystalline dolomite samples are concentrations of silt- and sand-size quartz grains (Plate 9, Figure 3). Dolomite crystals in a quartz-rich lamina are larger than crystals in the overlying relatively quartz-free lamina. These two layers comprise a small-scale graded bed in which the silt-size quartz grains and larger carbonate particles settled to the bottom first, and were then directly overlain by the smaller carbonate particles still in suspension. These cyclical laminae might be produced by periodic disturbances that churned up the material accumulating on the surface of sedimentation, or they may have been produced by periodic influxes of suspended sediment that was allowed to settle in a calm, possibly restricted region.

Streaks and mottling composed of quartz grains and clay material are most commonly developed in samples of medium-coarsely crystalline dolomite (see Plate 9, Figures 5 and 6). The insoluble material that composes these structures had to be moved to and concentrated in the area of accumulation. Thus, the final shape of these concentrations is controlled in part by the currents that winnow the insoluble material, and by slumpage, differences in rate of compaction, and reworking by bottom-dwelling organisms. The shapes of streaks and mottling expressed as differences in carbonate crystal size might also be controlled by these same factors (Plate 9, Figures 7 and 8).

Many finely and medium-coarsely crystalline dolomite samples in the Nittany Formation lack laminae, streaks or mottling, and are referred to as structureless (see Plate 9, Figures 1 and 2). These samples contain some insoluble impurities, but this material is distributed uniformly throughout the sample. Reworking of the sediment by burrowing organisms or the continuous churning up of the sediment by bottom currents could produce such a uniform distribution of insoluble material.

Alteration to Dolomite

The medium and coarsely crystalline dolomites from the Nittany Formation that contain fossils, oolites and pellets quite probably were originally deposited as calcium carbonate. However, positive evidence denoting the original composition of finely crystalline dolomites from the Nittany is lacking. In this study the writer assumes that all of the carbonate sediments that form the dolomites of the Nittany Formation were originally calcium carbonate, and that these calcitic sediments were later altered to dolomite.

An environment favorable for the transformation of calcium carbonate to dolomite would require an increased concentration of magnesium. Such an environment could be developed in a broad shallow basin separated from the sea by a barrier. The restricted waters could be warmed by the sun, and the resulting evaporation would increase the magnesium con-

centration. Calcitic sediments trapped within the basin and in contact with the magnesium-rich waters would alter to dolomite. In addition, previously deposited loosely packed calcitic sediments also could be altered to dolomite if the denser magnesium-rich waters were able to circulate below the water-sediment interface. Should the barrier periodically break, additional fine-grained sediments could be moved into the basin and sea water would replenish the water lost by evaporation. A region where magnesium-rich waters are produced in an environment ". . . isolated from the sea by a low coral rubble ridge . . ." is described by Deffeyes and others (1964, p. 678). In addition, they report that previously deposited calcitic sediments apparently have been altered to dolomite by a subsurface flow or reflux of these hypersaline waters from the bottom of the shallow basin back to the sea.

No mention has been made concerning the dolomitization of coarser grained calcitic sediments. These sediments probably formed and accumulated in a broad, warm and shallow sea. Should the surface of sedimentation rise, the shoreline would shift toward the sea, and shallow restricted basins could develop over sediments previously deposited in the open ocean. If these sediments remain loosely packed, then the denser magnesium-rich waters developed in restricted basins could circulate below the water-sediment interface and alter the calcitic sediments to dolomite.

In summary, the calcitic sediments that form the dolomites of the Nittany Formation, shortly after their deposition, most probably were altered to dolomite by magnesium-rich waters that formed by the evaporation of waters trapped in shallow restricted basins. Periodic shifts in the position of the open sea and restricted hypersaline environments produce conditions favorable for the dolomitization of all previously deposited calcitic sediments.

PALEOGEOGRAPHY OF THE NITTANY DOLOMITE

Schuchert (1955) shows about two-thirds of Pennsylvania and large parts of adjoining states covered by an extensive body of marine water during Early Ordovician time. This sea extends southwestward from Newfoundland into the eastern United States and continues westward into the central and southwestern states. The widespread geographic distribution of several Lower Ordovician faunal assemblages, such as the *Lecanospira* Zone in the Nittany Dolomite of Pennsylvania, the Rockdale Run Formation of Maryland, the Longview Limestone of Tennessee and the Roubidoux Formation of Missouri, indicate conditions favoring unrestricted circulation throughout the sea during most of this time.

In Pennsylvania, the Early Ordovician sea apparently was restricted to a northeast-trending belt several hundreds of miles wide and bordered on

the northwest by a large interior land mass and on the southeast by a narrow land area (Schuchert, 1955). The bordering land areas were relatively low and supplied only minor amounts of detrital material. Shallow-water open seas favored the precipitation of calcium carbonate and the growth of gastropods, brachiopods, sponges, cephalopods and trilobites over broad shelf-like regions. Restricted environments developed in several near-shore areas along the western shoreline in Pennsylvania. Periodic subsidence and sedimentary upbuilding of the surface of sedimentation on the shelf caused repeated shifts in the position of the western shoreline. Evaporation of the sea water in restricted environments produced magnesium-rich waters in regions where open-ocean conditions had formerly existed, and previously deposited coarse-grained calcitic sediments, made up in part of oolites, pellets, fossil debris and rock fragments, were altered to dolomite. The distribution of silt- and sand-size quartz grains in dolomite beds from the Nittany Formation (Plate 24) indicates that minor amounts of this detrital material were supplied from the northwest and north during the deposition of the Forge Union Member and from the west during the accumulation of the Etna Furnace Member.

By means of a preliminary isopachous map, Swartz (1948) indicates that the Beekmantown Group reaches a maximum thickness exceeding 4,000 feet in central Pennsylvania. In addition, he shows the axis of maximum accumulation trending northeast-southwest through central Pennsylvania. In central Pennsylvania, the area investigated in this study, the Nittany Dolomite is about 1,200 feet thick at Bellefonte, and to the southwest it thins to between 800 to 1,000 feet in central Bedford County. Throughout this region the Nittany Formation is composed entirely of beds of dolomite, whereas to the southeast in Chambersburg, Franklin County, Pennsylvania, and in the vicinity of Hagerstown, Maryland, formations equivalent in age to the Nittany Formation are composed of limestone with some interbeds of dolomite and contain little or no sand.

SUMMARY AND CONCLUSIONS

1. The Nittany Dolomite, named by Ulrich in 1911, is a 1,200-foot-thick sequence of dolomite. At the type section in Bellefonte it is underlain by the Stonehenge Limestone and overlain by the Axemann Limestone.

2. In the vicinity of Bellefonte the Nittany Dolomite is separated into three members on the basis of presence versus absence of detrital silt- and sand-size quartz grains. Many dolomite beds in the lower Forge Union Member and upper Etna Furnace Member contain silt- and sand-size quartz

grains, whereas few if any dolomite beds in the middle Shoenberger Member contain silt- and sand-size quartz grains. The upper part of the Forge Union Member is characterized by cycles made up of beds of dark-grey, coarsely crystalline, mottled dolomite, many of which contain oolites, pellets and fossils, and beds of light-grey, finely crystalline dolomite that contain silt- and sand-size quartz grains concentrated into laminae. The Shoenberger Member is an interbedded sequence of beds of medium- to dark-grey, medium to coarsely crystalline, mottled, structureless or streaked dolomite. Parts of the Etna Furnace Member are composed of dolomite cycles that resemble cycles developed in the Forge Union Member. However, beds of finely crystalline dolomite in the Etna Furnace Member are light-medium to medium grey and are commonly structureless rather than laminated. Beds and nodules of chert are distributed throughout the formation but occur most abundantly in the middle portion of the Forge Union Member.

3. The three members of the Nittany Dolomite recognized at Bellefonte were traced southwestwardly to Lutzville in central Bedford County along several outcrop belts exposed in the eroded anticlinal valleys which form the Nittany Arch. Lithologic characteristics of each member observed at Bellefonte remain essentially unchanged in the area of investigation. However, the Forge Union Member thins from 580 feet at Bellefonte to 450 feet at Lutzville; the Shoenberger Member thins from about 500 feet at Bellefonte to 300 feet at Lutzville; the Etna Furnace Member thickens from 180 feet at Shoenberger to about 320 feet at Lutzville.

4. Several species of *Lecanospira* occur in the uppermost 200 feet of the Forge Union Member. Specimens of *Cryptozoon steeli,* preserved in chert, occur throughout the lower half of the member. *Ophileta* sp. and *Lytospira* sp. were collected near the top of the Forge Union Member at Bellefonte. Fossils occurring in this member, but not previously identified in the Nittany Dolomite, include *Diaphelasma pennsylvanicum* and *Syntrophinella* cf. *S. cooperi*.

Silicified endoceroid siphuncles identified as cf. *Platysiphon,* cf. *Clitendoceras* and cf. *Proterocameroceras* were the only fossils collected in the Shoenberger Member. None of these forms have been previously identified in the Nittany Dolomite.

Tritoechia pennsylvanica, Finkelnburgia sp., *Diparelasma* sp., *Ophileta* cf. *O. solida, Orospira* sp. and oxeakloster sponge spicules were collected from dolomite beds in the Etna Furnace Member. *Orospira* is the only form previously reported as occurring in the Nittany Dolomite.

5. Where the Stonehenge Limestone is present, the Nittany Dolomite-Stonehenge Limestone contact is placed directly above the highest bed of limestone or dolomite containing fossils reported from the *Bellefontia* Zone at the top of the Logan Branch Member of the Stonehenge Limestone in

Bellefonte. Southwest of Bellefonte, in east-central Blair County, limestone beds in the Stonehenge Limestone completely disappear and the Nittany Dolomite is underlain by the Larke Dolomite. Donaldson (1959) demonstrated that the Stonehenge Limestone interfingers with the Larke Dolomite. The contact between the Nittany Dolomite and Larke Dolomite is placed above the highest bed of dark-grey, coarsely crystalline, oolitic dolomite containing fossils that occur in the *Bellefontia* Zone of the Stonehenge Limestone at Bellefonte. In addition to fossils previously reported by Donaldson (1959) and others from the *Bellefontia* Zone, the writer discovered four morphologically different forms that are tentatively identified as amphineuroid plates.

6. At the Shoenberger and Lutzville sections limestones of the Axemann Limestone are missing and the Nittany Dolomite is overlain by the Bellefonte Dolomite. In areas where the Axemann Limestone is missing, Butts (1939, 1945) placed the Bellefonte Dolomite-Nittany Dolomite contact midway between the base of the Nittany Dolomite and the top of the Bellefonte Dolomite. However, the writer places the contact at the top of the highest sandy dolomite bed in the Etna Furnace Member of the Nittany Dolomite.

7. Dolomites in the Nittany Formation are divided into ten lithotypes and five sublithotypes on the basis of dolomite crystal size and sedimentary structures. Rocks representing five of the dolomite lithotypes, finely crystalline structureless and laminated, and medium-coarsely crystalline structureless, mottled and granular, make up about 88 percent of the entire Nittany Dolomite. The Nittany Dolomite consists of a complex and repetitious succession of dolomite beds representing all lithotypes and sublithotypes recognized in this study.

8. The original carbonate sediments that make up dolomite beds in the Nittany Formation are believed to have been deposited as calcium carbonate on a broad shelf overlain by warm, shallow, freely circulating marine water. Bottom-dwelling organisms, including gastropods, brachiopods, sponges and trilobites, flourished throughout the region. Bottom currents aided in the formation and accumulation of oolites, pellets, rock fragments, and abraded shell material, but removed most of the very fine-grained carbonate sediment to restricted near-shore regions.

The fine-grained carbonate material, together with changing amounts of detrital silt- and sand-size quartz grains and clay minerals derived from nearby low-lying land areas, became trapped in broad, shallow, near-shore basins separated by a barrier from the open sea. Evaporation in these restricted basins increased the concentration of magnesium, and calcitic sediments in contact with the magnesium-rich water altered to dolomite. From time to time the barrier was broken and the basins received additional carbonate and noncarbonate sediments and sea water.

Carbonate sediments accumulated at nearly the same rate that the surface of sedimentation was subsiding, but periodic changes in the position of the surface of sedimentation caused the shoreline to shift back and forth. Thus, magnesium-rich waters produced in shallow, near-shore, restricted basins periodically covered sediments that formed and accumulated in the open sea. The dense magnesium-rich waters circulated through the loosely consolidated, more coarsely crystalline calcitic sediments and transformed them to dolomite. In this manner, fine-, medium-, and coarse-grained calcitic sediments were transformed to dolomite by the replacement of calcium by magnesium obtained from magnesium-rich water.

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APPENDIX A—SYSTEMATIC PALEONTOLOGY

Fossil Specimen Identification System

The notation used to catalogue specimens collected from the Nittany Dolomite and adjacent formations during the course of this study consists of four parts. From left to right, letters and numbers are used to denote the following items; formation, measured section, unit in section, specimen from unit. The letter code used is shown below.

Formation	*Measured Section*
A—Axemann Limestone	A —Axemann
	Bf —Bellefonte
N—Nittany Dolomite	Wb—West Bellefonte
	Sp —Spring Creek
S—Stonehenge Limestone	Bv —Baileyville
	S —Shoenberger
L—Larke Dolomite	SC —Spruce Creek
	ME—Mount Etna
	Wb—Williamsburg
	CC—Clover Creek
	Ws —Waterside
	L —Lutzville

The following example illustrates how the notation is read. Specimen N-Wb-36-3 is the third sample catalogued from unit 36 for the Williamsburg section of the Nittany Dolomite.

ANIMALIA

Phylum Porifera

Sponge Spicules

Pl. 19, fig. 1

Description.—Spicules straight, although a few slightly curved perhaps due to deformation; circular in cross section; spicules considerably longer than wide and tapering gradually to a point at both ends; pointed ends broken off in most specimens; lengths of well terminated spicules range between 0.8 to 1.2 mm; diameters range between 0.05 to 0.08 mm. Called oxeaklosters by Butler (1961).

Spicules siliceous; rough outer surface perhaps caused by modification to microcrystalline quartz; some spicules include yellowish-brown grains probably resulting from alteration of pyrite.

Skeletal structure and form of sponge unknown; assemblage consists of several hundred spicules.

Occurrence.—Nittany Dolomite, Shoenberger section, from beds located about 125 and 190 feet below top, in Etna Furnace Member.

Butler (1961) reports the occurrence of oxeaklosters 935 feet stratigraphically below the top of the Bellefonte Dolomite at his Union Furnace section which is located less than one-half mile southwest of the Shoenberger section. The spicule-bearing beds in the Bellefonte are located approximately 800 to 900 feet stratigraphically above the upper spicule-bearing bed of the Nittany. The range in size of oxeaklosters collected from the Nittany is nearly the same as the range reported by Butler (1961) for the oxeaklosters obtained from the Bellefonte.

Phylum Brachiopoda

Genus Finkelnburgia Walcott, 1905

Finkelnburgia cf. F. bridgei Sando

(not figured)

Finkelnburgia bridgei Sando, 1957, p. 113, Pl. 12, figs. 18-24.

Description.—Shell subelliptical, length approximately two-thirds the width; surface multicostellate, costellae solid; lateral profile subequally biconvex, pedicle valve more convex than brachial valve.

Pedicle valve moderately convex in lateral profile; beak low but conspicuous; pseudospondylium well developed, terminates in short, thick median ridge extending to about middle of valve; deltidium missing.

Brachial valve gently convex in lateral profile; median sulcus shallow and poorly developed; beak inconspicuous; brachiophore supporting plates short and delicate.

Measurements (mm)

	Length	Mid-width	Hinge width	Depth	L/W
Pedicle	7.0?	9.5	9.0	3.0	0.74
Brachial	7.0?	10.5	6.5?	2.5	0.67

Discussion.—The silicified valves collected are more elliptical in outline than those of *Finkelnburgia wemplei* (Cleland) (refer to Ulrich and Cooper, 1938, p. 145, Pl. 27D, figs. 17-23). Their external features appear to be similar to those displayed by *F. plicata* Ulrich and Cooper (1938, p. 142, Pl. 26B, figs. 11-14), but because the internal features of this species are not illustrated the Pennsylvania specimens are tentatively identified as *F. bridgei* Sando.

Occurrence.—Stonehenge Limestone, Baileyville section, 0—20 feet below top, in Logan Branch Member. Larke Dolomite, Mount Etna section, unit 5, 24—28 feet below top.

Silicified specimens of *Lytospira? multiseptarius* and *Ribeiria* cf. *R. parva* also occur in both of these units.

FINKELNBURGIA sp.
Pl. 15, fig. 1, 2

Description.—This genus is represented by one incomplete silicified brachial valve. Outline of shell orthoid in appearance; valve profile moderately convex; costellae radiating from beak well developed.

Measurements (mm)
Brachial Valve

	Length	Mid-width	Hinge width	Depth	L/W
N-ME-175-1 (figured)	6.5	8.5	8.0	—	0.76

Discussion.—The orthoid external appearance and size of the shell indicate that it belongs to *Finkelnburgia.* It compares favorably with *F. virginica* Ulrich and Cooper (1938, p. 144, Pl. 27E, figs. 24-32), but is too poorly preserved to permit specific designation.

Occurrence.—Nittany Dolomite, Mount Etna section, unit 175, 1,059.2 feet above base, in Etna Furnace Member.

Genus DIPARELASMA Ulrich and Cooper, 1936
DIPARELASMA sp.
Pl. 15, fig. 3-6

Description.—Silicified valves found in each of two beds in the Etna

Furnace Member at the Mount Etna section are for the most part badly broken and damaged; however, four are sufficiently complete to permit reference to the genus *Diparelasma,* even though specific identification remains uncertain.

Shell small; valves unequally biconvex, pedicle valve more convex than brachial valve; pedicle interarea longer than brachial interarea; delthyrium and notothyrium open; surface multicostellate.

Discussion.—The small size, overall appearance of valves, and the presence of an open delthyrium and notothyrium are the distinctive features used to assign the specimens to the genus *Diparelasma.*

Occurrence.—Nittany Dolomite, Mount Etna section, units 153 and 173, 962.6—964.9 feet and 1,053.0—1,055.1 feet above base, respectively, in Etna Furnace Member.

According to Ulrich and Cooper (1936) all but one of 16 named and unnamed species of this genus were collected from Upper Canadian beds. The oldest of these species, *D. silicum,* occurs in the Powell Formation of Arkansas and Missouri. They place the Powell near the top of the Upper Canadian, thereby correlating it with the Axemann Limestone and Bellefonte Dolomite or central Pennsylvania. Sando (1957) reports the occurrence of two species of *Diparelasma* in the *Diparelasma* Zone of the Rockdale Run Formation in Maryland, which he correlates with the Axemann Limestone in the vicinity of Bellefonte. The specimens of *Diparelasma* sp. collected by the writer occur in the Nittany Dolomite approximately 45 and 140 feet below the base of the Axemann Limestone at the Mount Etna section. Lees (1964) collected specimens of *Diparelasma* cf. *D. elegantulum* from limestone beds located approximately 80 feet above the base of the Axemann at Mount Etna. He also noted that the Axemann thins from about 400 feet at Bellefonte to approximately 240 feet at Mount Etna. This reduction in thickness probably results from the dolomitization of some of the limestone in the Axemann. Thus, the occurrence of *Diparelasma* sp. in dolomites near the top of the Nittany may be either the result of a facies change in the lower part of the Axemann from limestone to dolomite or may represent an extension of the range of this genus into beds lower in the Late Canadian.

Genus TRITOECHIA Ulrich and Cooper, 1936

TRITOECHIA PENNSYLVANICA Ulrich and Cooper

Pl. 15, fig. 7-18
Pl. 16, fig. 1-4

Tritoechia pennsylvanica Ulrich and Cooper, 1938, p. 165, Pl. 32D, figs. 17-22, 26.

Description.—Shell subelliptical to subquadrate in outline; lateral profile unequally biconvex, pedicle valve about twice as deep as brachial valve; surface of both valves marked by moderately strong, continuous, rounded costellae; costellae more strongly developed on pedicle valve.

Pedicle valve strongly convex in lateral profile; hinge line equal to width; cardinal extremities obtuse; interarea long, flat, strongly apsacline; fine radial lines radiating from beak marking its surface; deltidium convex, strongly elevated, tapering gradually to beak; perforated by longitudinally elliptical foramen. Dental plates sub-parallel; anterior commissure rectimarginate.

Brachial valve gently and evenly convex in lateral profile; umbo swollen; interarea short; cardinal process simple and erect, small; median ridge short.

Measurements (mm)

	Length	Mid-width	Hinge width	Depth	L/W
Pedicle Valve					
N-S-120-1 (figured)	12.5	13.5	13.5	6.0	0.93
N-S-120-2 (figured)	13.0	12.0	12.0	6.0	1.08
N-S-120-3	11.5	12.0	11.5	5.0	0.96
N-S-120-4	12.5	11.5	12.0	5.0	1.09
N-S-120-5	7.5	9.0	9.0	5.0	0.83
Brachial Valve					
N-S-120-6 (figured)	10.0	13.5	13.0	5.0	0.74
N-S-120-7	7.5	11.5	12.0	3.0	0.65
N-S-120-8	10.0	13.0	13.0	4.5	0.77
N-S-120-9	7.5	11.0	10.5	2.5	0.68
N-S-120-10	8.5	12.5	12.5	—	0.68
N-S-120-11 (figured)	7.5	9.5	11.0	3.0	0.79
N-S-120-12 (figured)	7.5	12.0	11.5	2.0	0.63

Discussion.—*Tritoechia pennsylvanica* resembles *T. typica,* but is distinguished by its finer ornamentation caused by narrower costellae that do not appear to be as hollow as those characterizing *T. typica.*

Occurrence.—Nittany Dolomite, Shoenberger section, units 115 and 120, 126.5—131.5 and 144.0—145.5 feet, respectively, below top, in Etna Furnace Member.

Silicified fragments of *Orospira* sp. were also collected from unit 120.

Most species of *Tritoechia* occur in beds located high in the Canadian

System (Ulrich and Cooper, 1938). In central Pennsylvania Lees (1964) collected specimens of *Tritoechia* cf. *T. pennsylvanica* at three sections of Axemann Limestone located between Graysville and Evergreen Farms, Huntingdon County, about eight miles northeast of the Shoenberger section. All species of *Tritoechia* collected by Sando (1957) in Maryland occur within the *Diparelasma* Zone, which he correlates with the Axemann Limestone in the Bellefonte area.

The Shoenberger section is located in a road cut that exposes an almost continuous sequence of rock from about the middle of the Nittany Dolomite to the base of the Reedsville Shale. The limestones of the Axemann are missing here.

The specimens of *Tritoechia pennsylvanica* and *Orospira* sp. collected by the writer occur in dolomite beds within a sequence of sandy dolomites. Lees' (1964) specimens of *Tritoechia* occur near the base of the Axemann Limestone within intervals composed of sandy limestones and dolomites. Thus, on the basis of lithologic and faunal similarities, it appears likely that some of the dolomites in the Etna Furnace Member at Shoenberger may be equivalent in age to limestone beds in the lower part of the Axemann Limestone. On the other hand, the occurrence of *T. pennsylvanica* in the Nittany Dolomite at the Shoenberger section may simply represent a downward extension of the stratigraphic range of this genus into older Canadian strata.

Genus Diaphelasma Ulrich and Cooper, 1936
Diaphelasma pennsylvanicum Ulrich and Cooper
Pl. 16, fig. 5-16

Diaphelasma pennsylvanicum Ulrich and Cooper, 1936, p. 629 (description only).—Ulrich and Cooper, 1938, p. 226, Pl. 49A, figs. 1-16, 21; B, figs.17-20, 22-25.—Cloud, 1948, p. 465, Pl. 3, figs. 28-48.—Sando, 1957, p. 124, Pl. 15, figs. 1-7, 9.

Description.—Shells unusually large, syntrophoid in appearance, slightly wider than long, broadly rounded lateral margins; valves unequal in depth, brachial valve deeper than pedicle valve; surface marked by fine concentric growth lines; stronger growth varices developed near anterior margin of pedicle valve.

Pedicle valve gently convex in lateral profile; beak elevated and incurved, umbo slightly swollen. Sulcus begins slightly posterior to middle of valve, fairly shallow and wide, culminates in long, bluntly pointed strongly genticulated tongue; spondylium simplex well developed.

Brachial valve flat to very slightly convex in lateral profile. Fold low, narrowly rounded, originating slightly posterior to middle of shell; flanks near anterior margin steeply sloped.

Measurements (mm)

Brachial Valve

	Length	*Mid-width*	*Hinge width*	*Length of tongue*	*Height of fold*	*Depth*	*L/W*
N-Bv-43-3 (figured)	9.5	12.0	7.0		4.8	4.8	0.79
N-Bv-43-4	8.0	10.5	6.5		3.0	3.0	0.76
N-Bv-43-5	—	13.0	8.0		—	—	—
N-Bv-43-6	7.5	10.0	5.0		2.5	2.5	0.75
N-Bv-43-7	6.0	7.0	4.0		2.0	2.0	0.86
			Pedicle Valve				
N-Bv-43-1 (figured)	10.0	10.5	6.5	4.0		3.0	0.95
N-Bv-43-2 (figured)	10.0	11.5	5.0	3.0		3.5	0.87
N-Bv-43-8	7.5	8.0	5.5	1.2		2.8	0.94
N-Bv-43-10	8.0	9.0	6.0	2.8		1.8	0.89
N-Bv-43-9	12.0	13.0	—	—		—	0.92

Discussion.—*Diaphelasma pennsylvanicum* is similar to, but larger than *D. oklahomense.* According to Ulrich and Cooper (1938, p. 227), *D. pennsylvanicum* is more like *D. quebecense* in its general configuration and size ". . . but differs in having a more swollen dorsal valve, more angular sulcus and tongue, and more conspicuous fold."

Occurrence.—Nittany Dolomite, Baileyville section, 372.3—382.1 feet above base, in Forge Union Member.

Genus SYNTROPHINELLA Ulrich and Cooper, 1934
SYNTROPHINELLA cf. S. COOPERI Sando
Pl. 17, fig. 1-19

Syntrophinella cooperi Sando, 1957, p. 125, Pl. 15, figs. 20-28.

Description.—Shell elliptical in outline; hinge line straight, less than half greatest width of pedicle valve, greater than half greatest width of brachial valve; sides rounded; profile unequally biconvex, brachial valve more convex; growth lines faintly developed; growth varices common near anterior margin of brachial valve; no radial ornamentation.

Pedicle valve moderately convex in umbonal region, gently convex or nearly flat to base of genticulated tongue; sulcus moderately deep, beginning slightly posterior from middle of shell, deepening and broadening anteriorly, ending in long, V-shaped, slightly rounded tongue bent 90°; beak slightly incurved, not prominent; spondylium simplex well developed.

Brachial vale convex, greatest convexity in umbonal region; fold prominent and angular, crest slightly rounded, developed to middle of shell; umbo strongly arched; interarea short and narrow.

Measurements (mm)

	Length	Mid-width	Hinge width	Length of tongue	Height of fold	Depth	L/W
Brachial Valve							
N-Wb-47-6 (figured)	7.0	9.5	5.5		4.0	4.2	0.74
N-Wb-47-7 (figured)	8.5	10.5	6.0		5.0	5.5	0.81
N-Wb-47-8	7.2	9.5	5.0		4.0	4.5	0.76
N-Wb-47-9	7.5	11.0	6.0		4.0	4.5	0.68
N-Wb-47-10	7.5	11.0	4.0		4.5	5.0	0.68
Pedicle Valve							
N-Wb-47-1 (figured)	6.5	8.0	4.0	3.0		2.5	0.81
N-Wb-47-2 (figured)	9.5	12.0	5.5	4.0		3.0	0.79
N-Wb-47-3	7.0	8.5	4.5	3.0		2.5	0.82
N-Wb-47-4	8.5	10.5	5.0	3.5		3.5	0.81
N-Wb-47-5	7.0	9.0	4.5	3.0		2.5	0.78

Discussion.—The fold in *Syntrophinella typica* (Ulrich and Cooper, 1938, p. 229, Pl. 50D, figs. 12-17, 21) extends nearly to the beak. On only the largest Pennsylvania specimens is the fold so strongly developed. Radial ornamentation is moderately well developed in *S. acutisulcata* (Sando, 1957, p. 124, Pl. 15, figs. 8, 10-19) but absent in the Pennsylvania shells. The size of the shells, length of the tongue, subdued ornamentation, and location of the beginning of the sulcus is nearly the same as the corresponding features in *S. cooperi*. Any radial ornamentation once present may have been worn off before the silification of the shells.

Occurrence.—Nittany Dolomite, Williamsburg section, 160.0-163.0 feet above base, in Forge Union Member. Other silicified specimens found in this unit include *Lecanospira* sp., *Ophileta* sp., and badly broken and damaged trilobite fragments.

Phylum MOLLUSCA

Class GASTROPODA

Genus LECANOSPIRA Butts, 1926

Lecanospira Butts, 1926, p. 93, Pl. 16, figs. 1-10.—Ulrich and Bridge, in Bridge, 1930, v. 24, 2d. ser., p. 203-204 (refer to this paper for a more complete synonymy of the genus).—Knight, 1941, p. 168.—Sando, 1957, p. 130-131.

Description.—Shell hyperstrophic, spire depressed below top of final whorl, bottom flat or just slightly concave. Shells composed of five to eight

whorls, whorls moderately to rapidly expanding, subtriangular to trapezoidal in cross section; prominent, pointed or slightly rounded keel developed on upper side of each whorl. Outer wall of each whorl vertical or nearly so, slightly convex; growth lines well developed on upper surface, missing on lower surface; sutures on lower surface very slightly depressed.

Discussion.—Following their description on the genus *Lecanospira,* Ulrich and Bridge (in Bridge, 1930) listed seven species. Four of these—*L. compacta* (Salter), *L. sigmoidea* Ulrich and Bridge, *L. salteri* Ulrich and Bridge and *L. biconcava* Ulrich and Bridge—were described in detail and illustrated. A fifth species, *L. conferta* Ulrich, is said to have the same distribution as *L. compacta* but it was not described or illustrated. These five species are widely distributed throughout North America in rocks of Early Ordovician age, i.e. the Middle Canadian of Ulrich. The other two species, *L. nerine* (Billings) and *L. alturensis* (Sardeson), occur in the Quebec Group, Division F, St. John, Newfoundland, and in the Oneonta Dolomite of Minnesota, Wisconsin and Iowa and the Gasconade Dolomite of Missouri, respectively. Both species occur in units older than the Roubidoux. Neither of these forms were described or figured, but Ulrich and Bridge describe them as being distinctly different from species found in the Roubidoux and its equivalents.

Another species, *L. sanctisabae* (Roemer), is illustrated but not described by Dake and Bridge (1932) and illustrated and briefly described by Bridge and Cloud (1947) and Cloud and Barnes (1948).

The features that distinguish this genus from other similarly appearing forms are so striking that even poorly preserved specimens can be confidently identified as *Lecanospira*. However, it is considerably more difficult to assign these forms to a particular species. In his description of the genotype for *Lecanospira* Bridge (1930) noted that the position of the keel on the dorsal side of each whorl and the cross section of the whorl are distinguishing specific characteristics.

On the basis of a comparison of his collection with type material of the five species found in the Roubidoux or its equivalents, Sando (1957, p. 130) recognized four criteria for separating his material into species; "depth of spire, depth of upper suture, rate of expansion of whorls and size." Nearly all these features are best seen in cross section. Unfortunately, the only cross sections illustrated in the literature are for *L. compacta,* probably the most distinctive species of the genus. The illustrations encountered are nearly always overhead views of either the upper or lower surface. The writer's identifications are based on comparisons made with descriptions and illustrations found in the literature. The identifications made are believed to be valid, but because this material was not compared directly with type specimens the specific identifications are subject to question.

Lecanospira has, in the past, been confused with *Ophileta*. These genera can be easily distinguished in a cross section through the center of the shell. *Lecanospira* has a flat base and a deeply depressed spire bordered by a prominent median keel on the outer whorl, whereas a section through a specimen of *Ophileta* reveals a strongly arched whorl profile.

Occurrence.—All occurrences are in the Forge Union Member of the Nittany Dolomite. In the vicinity of Bellefonte *Lecanospira* ranges from 410 to 570 feet above the base of the Nittany Dolomite. To the southwest the *Lecanospira* Zone ranges from 160 to 325 feet above the base. At Lutzville, however, it occurs at about the same stratigraphic position as at Bellefonte.

According to Sando (1958) the *Lecanospira* Zone in the Rockdale Run Formation of Maryland extends from 325 to 564 feet above the base of the formation. The *Lecanospira* Zone is about 150 to 175 feet thick in the Nittany Dolomite whereas Sando (1957) reports thicknesses of 116 feet, 156 feet and 173 feet for this zone at three different localities in Maryland.

Lecanospira compacta (Salter)

Pl. 18, fig. 1-4, 6, 7

Ophileta compacta Salter, 1859, p. 16-18, Pl. 3.—Bassler, 1919, p. 304, Pl. 33, figs. 1-3, Pl. 34, fig. 2.

Lecanospira (*Ophiletta*) *compacta* (Salter), Butts, 1926, p. 94, Pl. 16, figs. 1-2, 6-9.

Lecanospira compacta (Salter), Ulrich and Bridge, in Bridge 1930, p. 205, Pl. 22, fig. 1 (refer to this paper for a more complete synonymy of the species).—Knight, 1941, p. 169, Pl. 76, figs. 3a-c.—Knight, in Shimer and Shrock, 1944, p. 467, Pl. 189, figs. 32-34.—Sando, 1957, p. 131-132, Pl. 12, figs. 2, 4-5.

Description.—Large hyperstrophic shell composed of five or six whorls; spire deeply depressed; keel elevated and prominent, situated slightly off center toward outer wall; keel on last two whorls raises high above inner ones; base flat; outer wall almost vertical, gently convex; inner wall concave; lower two-thirds of body whorl has trapezodial cross section, upper one-third triangular cross section. Growth lines prominent on upper surface.

Measurements (mm)

	Maximum diameter	*Dorsal concavity*	*Height final whorl*
N-Wb-91-1 (figured)	28.5	11.0	—
N-Wb-91-2	19.0	4.0	7.0

Discussion.—The above description is based on two specimens obtained from the same piece of chert. Specimen N-Wb-91-1 is nearly complete and consists of an internal and external mold of the dorsal surface, whereas specimen N-Wb-91-2 is exposed only in cross section. *Lecanospira compacta* is distinguished by its relatively large size, the extreme concavity of the spire, the prominent, highly elevated keel that is developed on the outer two or three whorls, and the rapid rate of expansion of the whorls.

Occurrence.—Nittany Dolomite: Bellefonte section, 526.2-528.2 feet above base; northwest corner of excavation for addition to the Mineral Sciences Building on the campus of the Pennsylvania State University; Williamsburg section, chert float, 260.4-296.5 feet above base. All occurrences are within the Forge Union Member.

LECANOSPIRA cf. L. SALTERI Ulrich and Bridge
Pl. 18, fig. 8 and 9

Lecanospira salteri Ulrich and Bridge, in Bridge, 1930, v. 24, 2d. ser., p. 206, Pl. 22, fig. 3.—Butts, 1941, Pl. 70, fig. 10.

Description.—The description is based on the cross sections of five specimens whose shells have been replaced by dolomite.

Shell hyperstrophic, range from small to moderately large; spire deeply depressed; larger shells have five whorls; outer surface of keel continuation of convex surface of outer whorl wall; dorsal keel median, keel on body whorl leans slightly toward center of shell; keel on inner whorls located close to outer margin; whorls increase rapidly in height so that keel on inner whorl rises only slightly above suture; inner whorl wall concave; base flat.

Measurements (mm)

	Maximum diameter	*Dorsal concavity*	*Height final whorl*
N-Bf-56-1 (figured)	25.0	8.0	—
N-Bf-56-2	33.0?	—	—
N-Bf-56-3	12.0	2.5	—
N-Bf-56-4	20.5	—	—
N-Bf-56-5 (figured)	20.0	9.0	13.0

Discussion.—Several features that are critical to the recognization of *Lecanospira salteri* are visible in cross section. The keel on the inner whorls is only slightly elevated above the suture. In cross section, then, the upper surface of the shell appears as an almost smooth concave line interrupted only by the very small, V-shaped indentations of the keel on

the inner whorls. The deeply depressed spire, moderate size, and steep, slightly convex outer wall of the body whorl are also visible in cross section and serve to distinguish *L. salteri* from *L. sigmoidea*. The specimens examined are sufficiently similar to *L. salteri* to permit their comparison with this species.

Occurrence.—Nittany Dolomite, Bellefonte section, 511.5-516.8 feet above base, in Forge Union Member.

Lecanospira sp.
(Plate 18, fig. 5, 7, 10)

Description.—Large hyperstrophic shell; deeply depressed spire; prominent and sharp median keel; deep upper sutures, shallow lower sutures; base flat or just slightly concave; strongly developed growth lines on upper surface.

Discussion.—It is possible that two or more species are represented in the writer's collection of specimens. Although individual forms vary in size and shape, the features that distinguish this genus from superficially similar forms are sufficiently well preserved to permit identification.

Occurrence.—All occurrences are in the Nittany Dolomite; Bellefonte section, 409.9-533.4 feet above base; West Bellefonte section, 456.5-569.8 feet above base; northwest corner of excavation for addition to the Mineral Sciences Building on the campus of the Pennsylvania State University; Mount Etna section, 314.2-325.0 feet above base; Williamsburg section, 160.0-163.0 feet above base; Waterside section, 227.7-298.0 feet above base; Lutzville section, 400.0-450.0 feet above base.

Genus Lytospira Koken, 1896
Lytospira? multiseptarius (Cleland)
Pl. 20, fig. 5-9

Ecculiomphalus multiseptarius Cleland, 1900, p. 123 (251), Pl. XV, figs. 1-4.
Ecculiomphalus multiseptarius Cleland, 1903, p. 17.
Liomphalus? *multiseptarius* Fisher, 1954, p. 87, Pl. 4, figs. 4-5.
Lytospira? *multiseptarius* (Cleland), in Donaldson, 1959, p. 121-122, Pl. 16, figs, 3a-d.

Description.—This species is represented by numerous silicified specimens collected from insoluble residues. Nearly all specimens are incomplete; the best preserved specimens are the smaller forms.

Moderate to small sized, openly coiled, discoidal shell; earlier whorl depressed slightly below plane of later whorl; whorl profile subround to suboval, slightly wider than high; outer whorl face more convex rather

than inner whorl face, inner whorl face nearly flat in area of mid-height; transverse septa concave forward; shell wall rather thick; ornamentation unknown.

The largest specimen, although incomplete, measures 14 mm across the coil and has a maximum diameter of 5 mm. Other large specimens have diameters ranging from 3 to 5 mm. However, less than one-half of a whorl is preserved for any of these forms. There occur in the same residues similarly shaped but distinctly smaller shells. Although better preserved than the larger specimens, all of the smaller specimens also had less than one compete volution. These forms measure between 5 and 7 mm across the coil and have maximum diameters ranging between 1 and 2 mm.

Discussion.—Donaldson (1959) collected forms similar to those described above. He compared them to *Ecculiomphalus multiseptarius* Cleland on the basis of their moderate size and shape, and also noted that this form ". . . possibly belongs in the genus *Lytospira* Koken on the basis of its whorl profile" (Donaldson, 1959, p. 222).

These forms, however, lack the prominent angulation on the dorsal surface of the whorl, an important feature of *Lytospira*. It is possible that these siliceous specimens represent only the internal shell wall which may have a cross section unlike that of the shell exterior. For this reason Donaldson (1959) suggests that the forms be assigned to *Lytospira* until more complete and perfectly preserved specimens can be found.

The specimens collected from the Stonehenge and Larke Formations can be separated into two size classes. These two groups, however, may simply represent younger and older forms.

The specimens of *Lytospira* sp. collected from beds in the Nittany are larger than the Stonehenge-Larke forms. However, this may be the result of the more complete preservation of the Nittany forms.

Occurrence.—Stonehenge Limestone: Axemann and Spring Creek sections, in beds immediately below the Nittany-Stonehenge contact; Baileyville section, 0-19.3 feet below top; Spruce Creek section, 0-44.1 feet below top. Larke Dolomite: Mount Etna section, unit 5, 23.9-27.7 feet below top; Williamsburg section, 0-11.3 feet below top.

Commonly found in the same bed with *Lytospira? multiseptarius* are specimens of *Ribeiria* cf. *R. parva, Finkelnburgia* and several varieties of amphineuroid plates. These forms occur in the *Bellefontia* Zone in the upper 50 feet of the Stonehenge Limestone and Larke Dolomite.

LYTOSPIRA sp.
Pl. 19, fig. 2 and 3

Description.—Shell moderately large, openly coiled, discoidal; earlier whorl depressed slightly below plane of later whorl; whorl profile sub-

circular except for prominent angulation at middle of upper whorl surface; whorl wall subcircular on inner whorl surface and subangular on outer whorl surface. Ormanentation unknown; shell wall rather thick; septa developed in later whorl, concave forward.

The two specimens collected measure 28 and 30 mm across the coil, and have aperture diameters of 7 and 10 mm, respectively. Both specimens consist of less than one complete volution.

Discussion.—Lytospira sp. is represented by two incomplete, dolomitized specimens occurring in the same unit. In cross section they show the prominent angulation on the upper whorl surface, an important characteristic of the genus.

Occurrence.—Nittany Dolomite, Bellefonte section, 529.1-533.4 feet above base, in Forge Union Member. In this same unit occur dolomitized specimens of *Lecanospira compacta* and *Ophileta* sp.

Genus OPHILETA Vanuxem, 1842
OPHILETA cf. O. SOLIDA
Pl. 17, fig. 20 and 21

Ophileta solida Butts, 1926, p. 94, Pl. 16, fig. 11.—Butts, 1941, Pl. 69, fig. 19.

Description.—Low spired, discoidal, widely phaneromphalous; shells large; about 3 to 5 whorls, whorls subquadrangular in section, moderately expanding, upper surface very gently convex on inner half, very gently concave close to the peripheral angulation; upper suture on outer whorls sharply incised and shallow, lower sutures less sharply incised and shallower; section through nucleus shows strongly arched whorl profile, whorl profile distinctive feature of genus. Shells average about 35 mm in width; pleural angle averages about 131°.

Measurements (mm)

	Width	*Maximum height*	*Pleural angle*	*Umbilical angle**	*PA/UA*
N-ME-188-1 (figured)	33.0	12.0	137°	88°	1.56
N-ME-188-2 (figured)	39.0	—	128	56	2.28
N-ME-188-3	32.0?	16.0	117	51	2.29
N-ME-188-4	36.0	12.0	153	85	1.80
N-ME-188-5	24.0	—	122	68	1.79
N-ME-188-6	42.0?	—	130	77	1.69
N-ME-188-7	36.0?	12.0	131	81	1.62
Average	34.6		131°		

(*—angle of divergence of umbilical sides in cross section)

Discussion.—Many specimens that are now assigned to the genus *Lecanospira* Butts, 1926, were previously classified as species of *Ophileta* Vanuxem, 1842. The characteristic features of *Ophileta* were based on Salter's description of the genus which, unfortunately, was made from specimens that resembled Vanuxem's types but were actually quite different. In his description Salter emphasized two features, a depressed concave spire and a flat open umbilicus, that are not developed on either of Vanuxem's species (Bridge, 1930). Ulrich recognized this inconsistency and proposed the name *Lecanospira* for specimens of the type described by Salter.

The specimens collected by the writer are dolomitized and they occurred in a matrix of oolitic dolomite. The upper shell surface is poorly preserved on the weathered dolomite surface, but a cross-section through the nucleus reveals a well preserved whorl profile. The description and measurements are based entirely on these profiles.

The specimens identified as *Ophileta* cf. *O. solida* differ from *Lecanospira* by having a strongly arched whorl profile. They have a higher spire, and therefore a smaller pleural angle, are wider, and apparently have more rapidly expanding whorls than *O. complanata* Vanuxem.

Occurrence.—Nittany Dolomite, Mount Etna section, unit 188, 1091.4-1096.4 feet above base, in Etna Furnace Member. Poorly preserved, very high-spired and narrow gastropods resembling *Coelocaulus* were also observed in this unit.

Ophileta cf. *O. solida* occurs in the *Bathyurellus latimarginatus* Subzone of the Axemann Limestone (Macauley, 1952), and was collected by Lees (1964) from beds in the Rockview Member of the Axemann Limestone throughout central Pennsylvania.

The specimens collected by the writer occur above dolomite beds containing *Diparelasma* sp. and about 16 feet below the lowest limestone bed in the Axemann.

OPHILETA sp.
(not figured)

Description.—Shell small, low-spired, very narrowly phaneromphalous; umbilicus deep and very narrow; about 3 or 4 whorls, whorl profile subquadrangular, about 1.5 times higher than wide; periphery acutely angular; sutures deep on umbilical side, shallower on upper surface; shell very thin.

Measurements (mm)

Width	*Maximum height*	*Pleural angle*	*Umbilical angle*	*PA/UA*
16.0	7.5	128°	40°	3.21

Discussion.—The description is based on the whorl cross-section of one dolomitized specimen having the general spire profile and whorl cross-section of *Ophileta*. It is larger than *O. levata* and smaller than *O. complanata* or *O. solida*. In the same rock in which *Ophileta* sp. occurs there is an incomplete whorl profile that is about the same size as the profile of an outer whorl of *O. solida,* but the whorl has a slightly different shape. The pleural angle—umbilical angle ratio for *Ophileta* sp. is considerably larger than any of the ratios calculated for *Ophileta* cf. *O. solida*. *Ophileta* sp., however, may simply represent an immature form of this, or some other species.

Occurrence.—Nittany Dolomite, Bellefonte section, 529.1-533.4 feet above base, in Forge Union Member. Specimens of dolomitized *Lecanospira* sp. and *Lytospira* sp. were also collected from this unit.

Donaldson (1959) found specimens of *Ophileta* in the Stonehenge, and Lees (1964) and Macauley (1952) collected representatives of *Ophileta* in the Axemann of central Pennsylvania. Sando (1957) collected samples of cf. *Ophileta* sp. in the *Lecanospira* Zone of the Rockdale Run Formation in Maryland. Apparently this genus ranges from the Stonehenge through the Nittany and on into at least the lower part of the Axemann Limestone in central Pennsylvania.

Genus Orospira Butts, 1926

Orospira sp.

Pl. 19, fig. 4

Description.—Only one poorly preserved and incomplete silicified specimen of this genus was collected. The specimen is low spired and discoidal. Nodes are developed on the carina close to the upper suture and on the keeled whorl shoulder; sutures are sharply incised but shallow.

Discussion.—The one specimen collected by the writer is too poorly preserved and incomplete to permit a specific designation. However, noded carina, a characteristic element of this genus, are sufficiently well preserved and are the features used to assign the specimen to *Orospira*.

Occurrence.—Nittany Dolomite, Shoenberger section, unit 120, 126.5-131.5 feet below top, in Etna Furnace Member. Silicified shells of *Tritoechia pennsylvanica* were also collected from this unit. The discussion under "Occurrence" for *Tritoechia pennsylvanica* reviews the significance of the occurrence of these two forms in the upper part of the Nittany Dolomite.

Class Cephalopoda

Genus Proterocameroceras Ruedemann, 1905
cf. Proterocameroceras sp.
Pl. 19, fig. 5-8

Description.—The following description is based on one silicified specimen that is broken at the apical end and possibly incomplete at the adoral end. The cone is slender, straight, and slightly depressed in cross-section. At the broken apical end the endosiphocone is semi-circular and located closer to the ventral surface, which is slightly flattened. The endosiphocone, at the adoral end, conforms to the shape of the cone and is almost as large as the siphuncle, there being at this end only a very thin wall. The specimen is 33 mm long and 7 mm at the broken apical end, and increases uniformly to 10 mm in width at the adoral end. There appear to be flat septal markings but the replacing silica is so coarsely granular that this ornamentation is nearly obliterated.

Discussion.—The semi-circular endosiphocone and straight cone that is slightly depressed in cross-section are features that are characteristic of *Proterocameroceras.*

Occurrence.—Nittany Dolomite, Lutzville section, 450-500 feet above base, in Shoenberger Member.

Flower (1956) reports the occurrence of *Proterocameroceras* in the *Archaeoscyphia* Zone of the Rockdale Run Formation in Maryland.

Genus Clitendoceras Ulrich and Foerste, 1935
cf. Clitendoceras sp.
Pl. 19, fig. 9-11

Description.—The siphuncle is small, very slender and slightly curved. It is 47 mm long and about 9 mm wide, and reaches this maximum width about 30 mm above the posterior end. Septal markings are visible but poorly preserved. There are about 3 in a length of 5 mm near the adoral end of the specimen, but they are so poorly preserved that it is difficult to ascertain whether they are oblique or straight. The degree of curvature is small and confined to the apical half. At the apical end the siphuncle appears to be depressed and the end is blunt. The endosiphocone at the adoral end conforms to the subcircular shape of the siphuncle and is located centrally in the cone.

Discussion.—The specimen possesses the slight endogastric curvature and circular cross-section that is characteristic of *Clitendoceras.* It resembles *Mcqueenoceras* by having a curved cone, but it differs from this genus by having a narrow cross-section and a centrally located tube. The

proportions of *Clitendoceras* are similar to those described by Flower (1956) for *Clitendoceras subgracile*.

Occurrence.—Nittany Dolomite, Waterside section, 579.8-584.6 feet above base, in Shoenberger Member.

Flower (1956) described a suite of silicified endoceroid siphuncles collected by Sando (1957) from Beekmantown rocks in Washington County, Maryland. Flower identified two new species of *Clitendoceras* in this collection. Although specimens of *Clitendoceras* were found in the *Lecanospira* Zone they apparently occur most commonly in the overlying *Archaeoscyphia* Zone. *Clitendoceras subgracile* occurs in beds located in the *Archaeoscyphia* Zone 697 feet above the base of the Rockdale Run Formation (Flower, 1956).

Genus Platysiphon Flower, 1956
cf. Platysiphon sp.
Pl. 19, fig. 12-15

Description.—The siphuncle is very strongly depressed in cross section. The dorsal side is rounded but the ventral surface is nearly flat or just slightly concave upward. A rather faintly developed ridge extends along the apical half of the shell and is located slightly off center. The endocone is simple and conforms to the cross section of the siphuncle wall at the adoral end, but narrows more quickly toward the apical end than does the cone. The tube appears to end midway between the ends of the siphuncle. The apical end is blunt and about 4 mm wide; the cone increases in width uniformly to the adoral end. The specimen is 33 mm long but is incomplete to the adoral end. Twenty-two mm from its apex the cone is 9 mm wide. Oblique, low and rounded annuli are strongly developed on one side. There are about 12 over the entire length of the cone. The cone is just slightly curved and has a maximum thickness of about 4 mm.

Discussion.—The specimen has a very broad and depressed cross section, two features that are characteristic of *Platysiphon*. Like *Platysiphon* it is also slender and relatively straight. The siphuncle compares favorably in size with *P. expansum* Flower (1956).

Occurrence.—Nittany Dolomite, Lutzville section, 450-500 feet above base, in Shoenberger Member.

Platysiphon sp. occurs in beds located about 50 feet above beds containing the only specimen of *Lecanospira* sp. collected at Lutzville. Because the thickness and stratigraphic position of the *Lecanospira* Zone at this section is unknown the bed containing *Platysiphon* sp. is located either near the top of the *Lecanospira* Zone or near the base of the *Archaeoscyphia* Zone. Flower (1956) indicates that *Platysiphon* occurs within both of these zones in Maryland.

Phylum ARTHROPODA

Genus RIBEIRIA Sharpe, 1853
RIBEIRIA cf. R. PARVA Collie
Pl. 20, fig. 1-4

Ribeiria parva Collie, 1903, p. 419, Pl. 59, fig. 4, 5.—Donaldson, 1959, p. 264, Pl. 14, fig. 5a, 5b.

Description.—Carapace small, suboval, bilaterally symmetrical; autero-dorsal extremity notched, notch slightly greater than 1 mm wide, extends obliquely toward center of shell; straight or slightly convex dorsal margin about 8.0 mm long, "U"-shaped, nearly flat on top, considerably narrower than maximum width of shell; sloping steeply near anterior margin and less steeply at posterior margin; ventral margin semicircular; shell open slightly below notch at anterior end, remaining open along ventral margin.

Transverse internal plate beneath notch; plate 3.0 to 4.0 mm wide, about 1.0 mm thick. Because the silicified shells are extremely fragile none of the specimens collected were perfectly preserved. Thus, it is impossible to measure the length of any specimen. However, the height varies from 8.0 to 10.0 mm and the thickness ranges from 5.0 to 6.0 mm.

Discussion.—The species is smaller than *Ribeiria calcifera* Billings, and differs from *R. nuculitiformis* Cleland by lacking a fold or sinus, and is also smaller than this form.

Occurrence.—Stonehenge Limestone: Axemann and Spring Creek sections, in beds immediately below Nittany-Stonehenge contact; Baileyville section, 0-19.3 feet below top; Spruce Creek section, 0-44.1 feet below top. Larke Dolomite: Mount Etna section, unit 5, 23.9-27.7 feet below top; Williamsburg section, 0-11.3 feet below top.

Specimens of this species were collected only from insoluble residues. The carapace is well preserved but usually broken into small fragments. Fortunately, in this debris the antero-dorsal notch containing the transverse internal plate is commonly preserved (Plate 20, figure 3) and is easily identified. The internal plate is considerably stronger than the shell and is able to resist destruction. Commonly found in the same residue with *Ribeiria* cf. *R. parva* are specimens of *Lytospira*? *multiseptarius, Finkelnburgia* sp. and several types of amphineuroid plates. This assemblage is typical of the *Bellefontia* Zone at the top of the Stonehenge Limestone and Larke Dolomite, and it proved to be an invaluable aid in locating the base of the Nittany Dolomite at several sections.

INCERTAE SEDIS

Amphineuroid (?) plates
Pl. 20, fig. 10-25

Discussion.—Unusual, in part more or less V-shaped or chevron-like, silicified forms were discovered in insoluble residues of dolomites of the lower Beekmantown at four sections. There were, in these same residues, other silicified fossils that are commonly part of the assemblage reported from the *Bellefontia* Zone in the upper part of the Stonehenge Limestone and Larke Dolomite.

The chevron-like specimens, especially, are reminiscent of plates of some of the modern chitons. They were shown to E. L. Yochelson of the U. S. Geological Survey. He thought this identification was a reasonable possibility. The writer left with Yochelson a sample of dolomite from which he dissolved additional specimens. Yochelson later wrote the following:

> "The peculiar beast might be a chiton, though if it is, it is certainly a peculiar chiton. There are a large number of end plates, assuming that this is the correct guess. On the one hand, the attitude of the fossils in the rock clearly shows evidence of sorting, but on the other hand, there are a few smaller gastropods sorted into the area. Perhaps most of the intermediate plates of the chiton? were thinner and were broken" (personal communication).

None of these forms correspond closely to any of the various fossil Cenozoic chitons for which illustrations were found. The amphineuroid plates, as they questionably will be referred to, are separated into four types and are described below. Although the proper biologic position of these plates is unknown, their occurrences as so far observed make them potentially important guide fossils to the *Bellefontia* Zone of late Early Ordovician time.

Amphineuroid plates type I
Pl. 20, fig. 10-12

Description.—Plate rectangular-shaped, length slightly less than double width; upper surface flat or just slightly convex, narrow depression in center extending length of plate; depression deepest at one end becoming shallower or completely disappears at opposite end; edges of longest sides folded downward at angle of 90°, slightly convex outward; end where depression deepest also folded inward, opposite end not folded; lower surface flat, low ridge extends about half length, ridge forms underside of depression; lengths range from 4.0 to 8.0 mm; widths range from 5.0 to 7.0 mm; thickness ranges from 2.5 to 5.0 mm. The average specimen is 8.0 mm long, 6.0 mm wide and 3.5 mm thick.

Discussion.—Type I amphineuroid plates are easily distinguished from the other three types by their rectangular shape.

Occurrence.—Stonehenge Limestone, Baileyville section, 50.7-55.4 feet below top. Found in this same unit are the silicified remains of small, straight-shelled cephalopods, type III amphineuroid plates, and gastropod fragments similar to *Gasconadia putilla*. Stonehenge Limestone, Spruce Creek section, 0-44.1 feet below top. In this same unit occur the silicified remains of *Ribeiria* cf. *R. parva, Lytospira*? *multiseptarius,* and types II and III amphineuroid plates.

Amphineuroid plates type II
Pl. 20, fig. 13-15

Description.—Plate hastate-shaped, length almost double width; one end bluntly pointed, other end with U-shaped notch; upper surface steeply pointed, lower surface gently concave; dimensions of figured specimen: length—9.0 mm, width—5.0 mm, height—4.0 mm, depth of notch—2.5 mm.

Discussion.—Type II amphineuroid plates are shaped similarly to type III plates but they have a larger length to width ratio than type III. Type II also resembles type IV in shape, but type IV lacks a deep U-shaped notch at one end; type IV also possesses a pouch-like structure on its underside at the pointed end.

Occurrence.—Stonehenge Limestone, Spruce Creek section, 0-44.1 feet below top. The silicified remains of *Ribeiria* cf. *R. parva, Lytospira*? *multiseptarius* and types I and III amphineuroid plates also occur in this unit.

Amphineuroid plates type III
Pl. 20, fig. 16-18

Description.—Plate V-shaped, length less than width; one end bluntly pointed, other end with a deep V-shaped notch; upper surface steeply convex, lower surface gently concave; dimensions of figured specimen: length—6.0 mm, width—7.5 mm, height—4.0 mm, depth of notch—2.0 mm.

Discussion.—Type III amphineuroid plates have a shape similar to types II and IV but are distinguished from these two forms by having a width that exceeds length.

Occurrence.—Stonehenge Limestone: Baileyville section, 50.7-55.4 feet below top; Spruce Creek section, 0-44.1 feet below top. Larke Dolomite, Mount Etna section, unit 5, 23.9-27.7 feet below top. The silicified remains of *Lytospira*? *multiseptarius, Finkelnburgia* cf. *F. bridgei, Ophileta* sp. and *Ribeiria* cf. *R. parva* also occur within this unit.

Amphineuroid plates type IV
Pl. 20, fig. 19-25

Description.—Plates wedge-shaped, considerably longer than wide; one end bluntly pointed, other end either flat or with a slight U-shaped notch; upper surface steeply convex, lower surface less steeply concave. Pouch-like structure extends from the pointed end to slightly less than mid-length; pouch tends to fill in the concave underside forming a shallower and less steeply concave surface.

Measurements (mm)

	Length	*Width*	*L/W*
L-L-0-1 (figured)	12.0	4.5	2.67
L-L-0-2 (figured)	14.0	5.5	2.55
L-L-0-3 (figured)	17.0	7.0	2.43

Discussion.—The large length to width ratio and the pouch-like structure on the concave underside surface serve to distinguish this type of amphineuroid plate from the other three types. Type IV amphineuroid plates were found at only one locality, but they occurred there in such large quantities that they made up nearly one-half of the dolomite specimen. The specimens obtained at this locality display a rather wide range of sizes and shapes. However, the smaller forms appear to be broken at one end. These smaller plates have shapes similar to types II and III, and could possibly be confused with them if the pouch-like structure is broken off.

Occurrence.—Larke Dolomite, Lutzville section, about 100 feet below top. According to Yochelson (personal communication) this interval also contains more than eight types of gastropods. From this assemblage he identified several specimens of *Gasconadia* and *Ophileta.*

PLANTAE

INCERTAE SEDIS

Phylum SCHIZOPHYTA or CHLOROPHYCOPHYTA

Genus CRYPTOZOON Hall, 1883
CRYPTOZOON STEELI Seely
Pl. 18, fig. 11

Cryptozoon steeli Seely, 1905-6, p. 161-162, Pl. 34; 35; Pl. 37, fig. 1.

Description.—Hemispherically-shaped mass composed of very thin layers, layers nearly parallel and almost perfectly concentric with one another; broadest face flat, forms base upon which mass grows upward and outward; concentric mass has only one center of growth and is, in this sense, an individual. Masses range in size from several inches to about two feet in diameter.

Discussion.—In his original specific description Seely (1905-1906) describes *Cryptozoon steeli* as being a calcareous mass. All the specimens collected from the Nittany, however, have been replaced by chert. *Cryptozoon steeli* is characterized by its hemispherical shape, large size, and concentric layered structure.

Occurrence.—Nittany Dolomite, Lutzville section, 0-175 feet above base, in Forge Union Member. Specimens of *Cryptozoon steeli* were also found as residual chert float in many fields underlain by dolomite beds in the lower half of the Nittany Dolomite from Bellefonte southwestward to Lutzville.

APPENDIX B—MEASURED SECTIONS

Twelve sections of the Nittany Dolomite were measured and described during the course of the study (see list below). Included with this report are descriptions of the three most complete sections which, in addition, are type sections for newly named members of the Nittany. For detailed descriptions of the other nine sections the reader is referred to the original thesis (Spelman, 1965). The approximate location of each section in central Pennsylvania is shown in Figure 2. Detailed index maps indicating more precisely the location of the 12 sections are included in Appendix B as Figures 8, 9, 10.

Measured Sections of the Nittany Dolomite

Axemann Section	(No. 1)
Bellefonte Section	(No. 2)
West Bellefonte Section	(No. 3)*
Spring Creek Section	(No. 4)
Baileyville Section	(No. 5)
Shoenberger Section	(No. 6)*
Spruce Creek Section	(No. 7)
Mount Etna Section	(No. 8)*
Williamsburg Section	(No. 9)
Clover Creek Section	(No. 10)
Waterside Section	(No. 11)
Lutzville Section	(No. 12)

*—Sections included with this report.

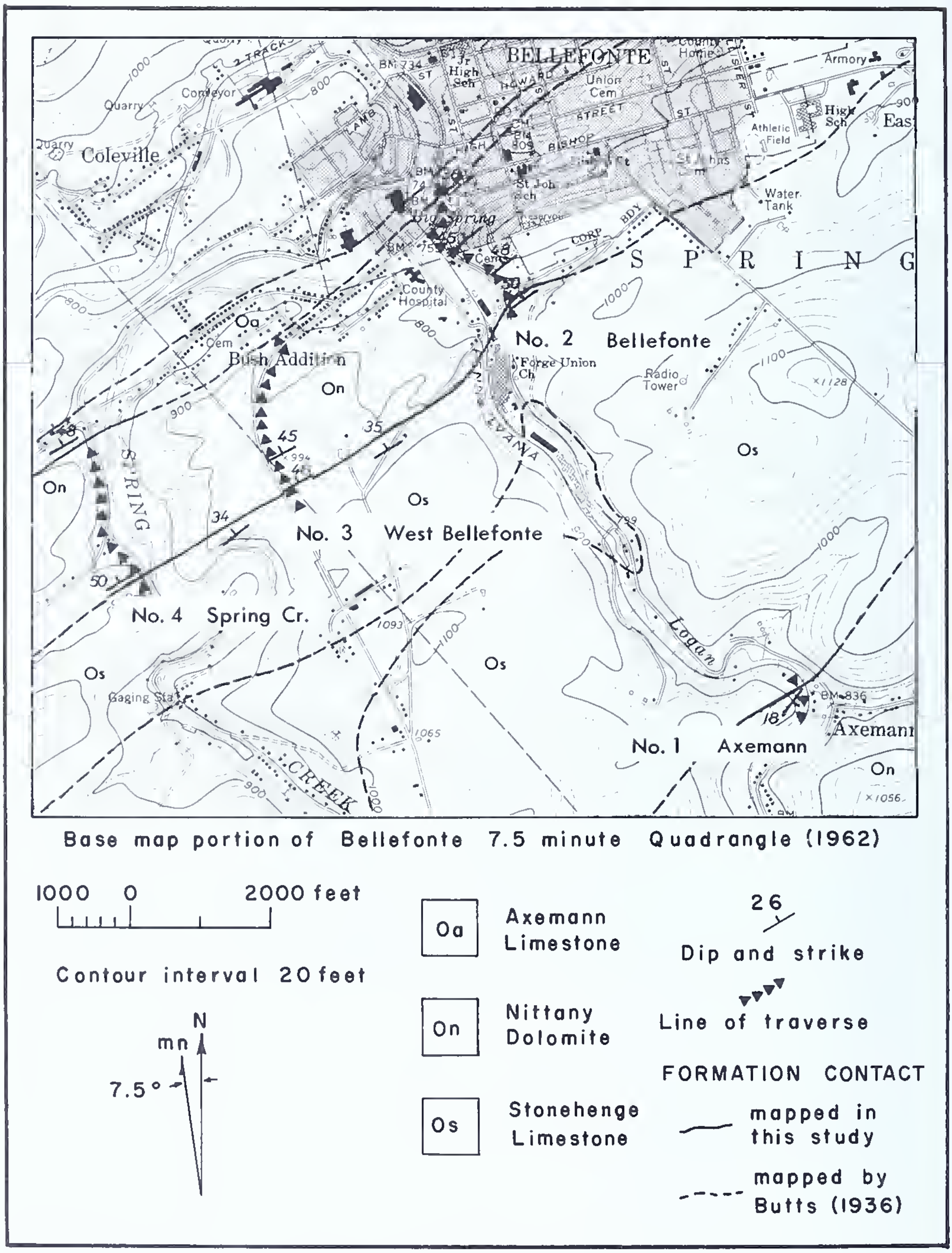


Figure 8. Index map for geologic sections of the Nittany Dolomite measured in the vicinity of Bellefonte, Pennsylvania.

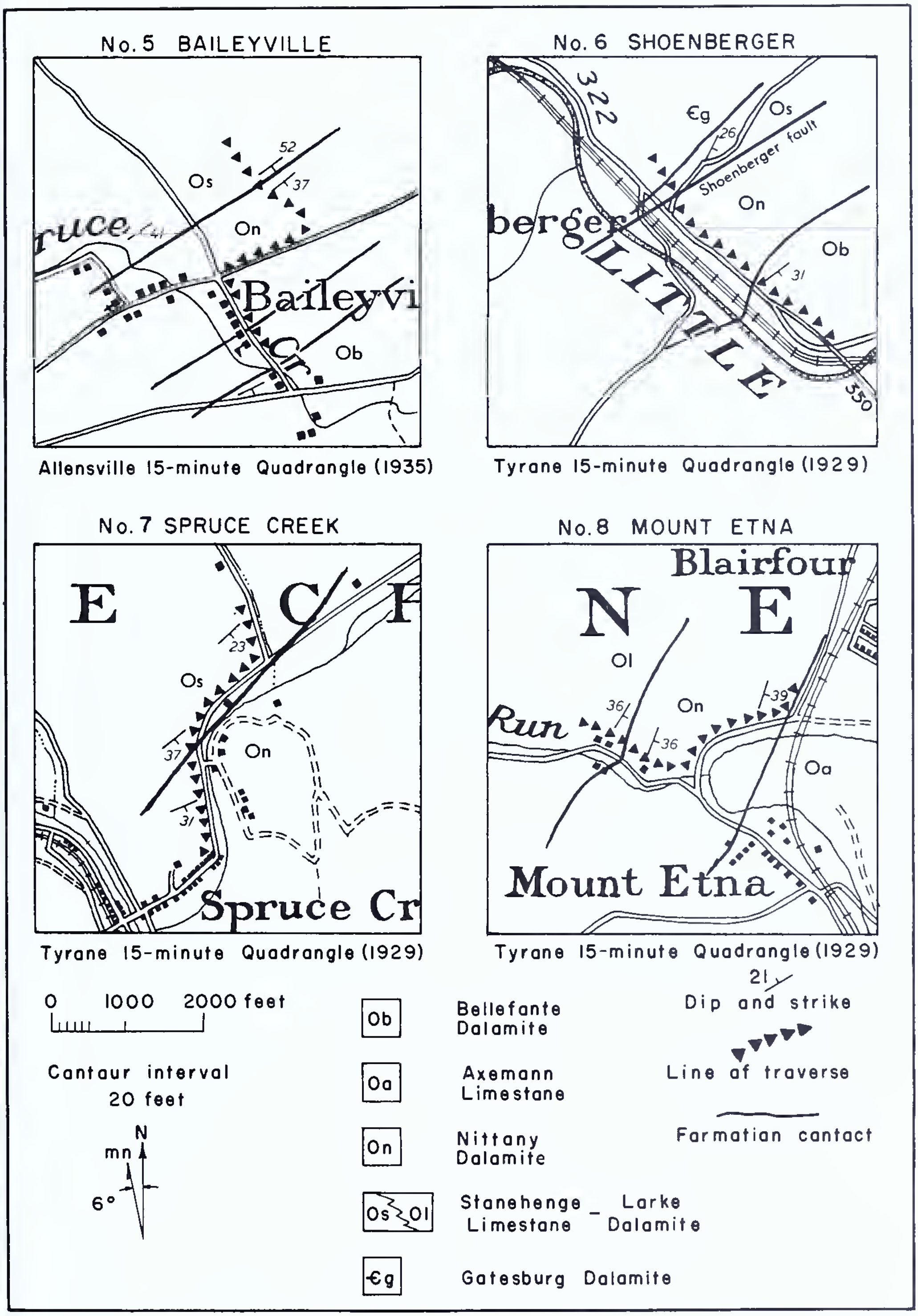


Figure 9. Index maps for geologic sections of the Nittany Dolomite measured near Baileyville, Shoenberger, Spruce Creek and Mount Etna, Pennsylvania.

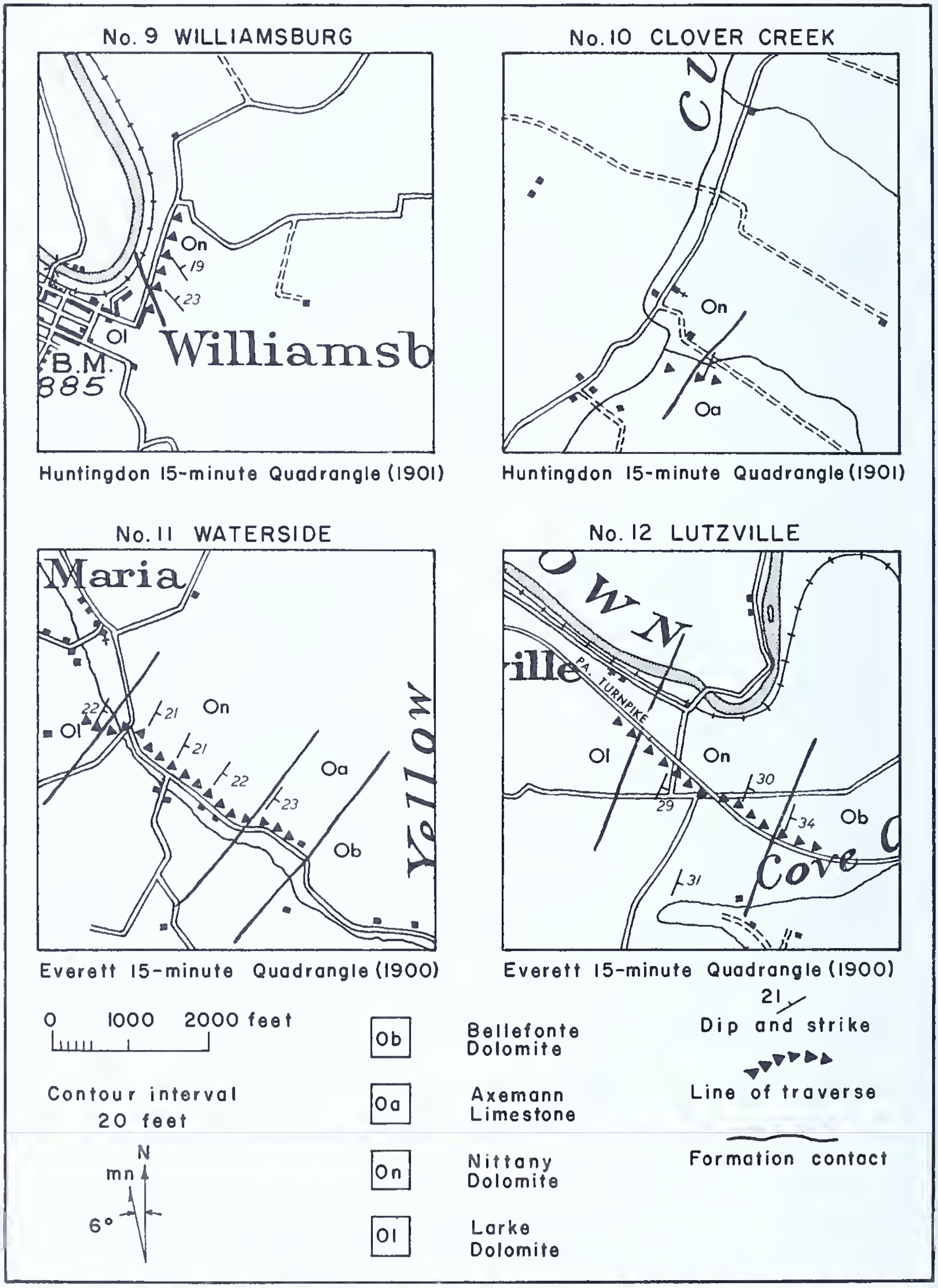


Figure 10. Index maps for geologic sections of the Nittany Dolomite measured near Williamsburg, Clover Creek, Waterside and Lutzville, Pennsylvania.

WEST BELLEFONTE SECTION

(No. 3)

The Nittany Dolomite is well exposed about one-half mile southwest of Bellefonte, Centre County, in a roadcut along Highway 26. The exposures are located in the southeastern part of the Bellefonte 7.5 minute quadrangle, and occur geologically in the northwestern limb of the Gatesburg anticline. The section begins at a point located 10,700 feet west of 77° 45′ west longitude and 8,350 feet north of 40° 52′ 30″ north latitude, and ends at a point located 10,850 feet west of 77° 45′ west longitude and 10,550 feet north of 40° 52′ 30″ north latitude. Beds strike from N. 48° E. to N. 59° E., but average between N. 52° E. and N. 56° E.; dip varies from 43° NW. to 48° NW. and averages 45° NW. (See Figure 8).

The Nittany Dolomite-Stonehenge Limestone contact is concealed. However, beds in the Stonehenge Limestone are exposed northeast of Highway 26 along a dirt road, and southwest of the highway on the north side of a cliff cut by a meander of Spring Creek. Dark-grey to black, coarsely crystalline, mottled dolomites occur about 140 feet northwest of the cliff. The Nittany Dolomite-Stonehenge Limestone contact was placed midway between the cliff and the exposed beds of dark-grey dolomite, and its location along Highway 26 was established by projecting from this point a line that is parallel to the average strike of these beds. This line, and a dirt road coming from a farm house east of the highway, intersect Highway 26 at nearly the same point.

The Axemann Limestone-Nittany Dolomite contact occurs within a concealed interval southeast of a two story white frame house that is located about 150 feet northwest of Highway 26 in Bush Addition. Calcarenites containing fragments of trilobites, brachiopods and crinoid plates are exposed in a ledge along the southwest side of the house. According to Lees (personal communication) rocks representing this lithotype occur most commonly about 100 to 200 feet above the base of the Axemann. The Axemann Limestone-Nittany Dolomite contact is arbitrarily placed about 70 feet stratigraphically below these fossiliferous limestone beds.

Abrupt changes in dip from 45° NW. to horizontal in unit 124, 762 feet above the base, indicate that the formation is folded or faulted. Poor exposures prevent a definite interpretation of the variation in dip. The thickness of the Nittany Dolomite at this section corresponds closely to the thickness measured at the Bellefonte section and to values generally attributed to the Nittany Dolomite in this region. If the formation is faulted at unit 124 the amount of stratigraphic displacement is not large.

The top of the Forge Union Member is located 580 feet above the Nittany Dolomite-Stonehenge Limestone contact; 350 feet or 60 percent of

this interval is exposed. The top of the Shoenberger Member is arbitrarily placed 1,100 feet stratigraphically above the base of the formation. About 50 percent of the Shoenberger, and less than 20 percent of the Etna Furnace Member are exposed.

The West Bellefonte section is designated as the type section for the Forge Union Member of the Nittany Dolomite. The name "Forge Union" is taken from the Forge Union Church which is located about three-quarters of a mile south of Bellefonte on Pennsylvania Highway 53.

Unit	Lithologic description	Thickness (feet) Unit	Total
Axemann Limestone			
	Limestone, aphanitic, mottled, dolomitic-streaked, dark-grey, weathering light grey. Gastropod, trilobite, brachiopod and crinoid plate fragments common.	4.0	1296.6
	Concealed. Includes Axemann Limestone-Nittany Dolomite contact. Contact placed 1,220 feet above base of Nittany.	87.7	1296.6
Nittany Dolomite			
Etna Furnace Member			
133.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, laminated, laminae irregular concentrations of yellowish-brown argillaceous material, dark-grey, weathering dark grey.	4.0	1204.9
132.	Dolomite, medium-crystalline, mottled by light-grey dolomite, medium-dark-grey, weathering medium grey. Vugs common.	3.0	1200.9
131.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, parts laminated, laminae irregular yellowish-brown-colored argillaceous material, dark-grey, weathering dark grey.	1.5	1197.9
130.	Dolomite, sandy, finely crystalline, laminated and banded, laminae due to more coarsely crystalline dolomite and sand-size quartz grains, 1-inch bed of quartzite near middle, light-grey, weathering light grey, 3- to 6-inch bedded.	3.7	1196.4
129.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, dark-grey, weathering dark grey.	3.3	1192.7
128.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey.	1.3	1189.4
127.	Concealed. Base of Etna Furnace Member placed 1,100 feet above base of Nittany Dolomite.	369.7	1188.1
	Thickness of Etna Furnace Member		120.0
Shoenberger Member			
126.	Dolomite, medium-crystalline, mottled, medium-grey, weathering medium grey, 4-inch to 1½-foot bedded.	35.0	818.4

Unit	Lithologic description	Thickness (feet) Unit	Total
125.	Concealed.	21.2	783.4
124.	Dolomite, coarsely crystalline, mottled, streaked by yellowish-brown argillaceous material, dark-grey, weathering dark grey, 2-inch to 1-foot bedded. Unit possibly faulted; dip ranges from 45° NW. to horizontal.	55.0	762.2
123.	Dolomite, finely crystalline, laminated, laminae due to more coarsely crystalline dolomite and color changes, light-grey, weathering light grey, 2- to 4-inch bedded.	2.5	707.2
122.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, oolitic near base, dark-grey, weathering dark grey. Solution cavities common on weathered surface.	11.2	704.7
121.	Dolomite, finely crystalline, laminated and banded, laminae due to more coarsely crystalline dolomite and color changes, light-grey, weathering light grey, one bed.	3.1	693.5
120.	Dolomite, coarsely crystalline, faintly mottled, dark-grey, weathering dark grey, one bed.	1.5	690.4
119.	Dolomite, medium-crystalline, laminated, laminae yellowish-brown argillaceous material, medium-grey, weathering medium grey, one bed.	4.4	688.9
118.	Dolomite, coarsely crystalline, mottled and streaked by light-grey dolomite, dark-grey, weathering medium dark grey, 2- to 4-inch bedded. Small high-spired gastropod molds rare.	8.0	684.5
117.	Dolomite, medium-crystalline, structureless, medium-grey, weathering medium grey. Vugs common.	1.9	676.5
116.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, dolarenite near center, parts laminated, laminae discontinuous irregular yellowish-brown argillaceous material, dark-grey, weathering dark grey.	3.1	674.6
115.	Dolomite, cherty, finely crystalline, laminated, medium-grey, weathering medium grey. Chert nodules, medium-grey, rare. Yellowish-brown argillaceous material along bedding surfaces.	4.4	671.5
114.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, upper foot dolorudite, pebbles dark-grey dolomite, center laminated, laminae irregular yellowish-brown argillaceous material, dark-grey, weathering dark grey.	3.7	667.1
113.	Dolomite, finely crystalline, structureless, medium-light-grey, weathering medium grey.	2.5	663.4
112.	Dolomite, coarsely crystalline, mottled, dark-grey, weathering dark grey. Extremely friable.	2.5	660.9
111.	Concealed.	13.6	658.4
110.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, medium-grey, weathering dark grey, 2- to 4-inch bedded. Vugs common.	3.7	644.8
109.	Concealed.	3.7	641.1

Unit	Lithologic description	Thickness (feet) Unit	Total
108.	Dolomite, medium-crystalline, structureless, medium-grey, weathering dark grey. Vugs common.	4.2	637.4
107.	Dolomite, finely crystalline, faintly mottled, medium-grey, weathering light grey. Vugs common.	1.8	633.2
106.	Dolomite, coarsely crystalline, mottled by very coarsely crystalline dolomite, dark-grey, weathering dark grey. Extremely friable and porous lower half.	4.2	631.4
105.	Dolomite, finely crystalline, laminated, laminae widely spaced and slightly irregular, light-grey, weathering light grey, one bed.	2.4	627.2
104.	Dolomite, medium-crystalline, dolorudite, lower 1 foot faintly laminated, dark-grey, weathering dark grey, 2-inch to 1-foot bedded.	3.6	624.8
103.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, 6-inch to 1-foot bedded.	3.6	621.2
102.	Dolomite, medium-crystalline, structureless, dark-grey, weathering dark grey, one bed. Vugs common.	0.6	617.6
101.	Dolomite, finely crystalline, laminated and banded, laminae due to more coarsely crystalline dolomite, light-grey, weathering light grey, 6-inch to 1-foot bedded.	4.8	617.0
100.	Dolomite, coarsely crystalline, mottled and streaked by light-grey dolomite, lower 1 foot dolorudite, pebbles dark-grey dolomite in medium-grey dolomite cement, dark-grey, weathering dark grey, 1- to 3-inch bedded.	7.7	612.2
99.	Dolomite, medium-crystalline, mottled, parts faintly laminated, laminae yellowish-brown argillaceous material, medium-grey, weathering medium grey. Vugs common.	3.0	604.5
98.	Dolomite, medium-crystalline, mottled, dark-grey, weathering dark grey.	1.2	601.5
97.	Dolomite, medium-crystalline, structureless, light-grey, weathering medium grey.	3.0	600.3
96.	Dolomite, medium-crystalline, structureless, medium-grey, weathering medium grey, one bed.	1.8	597.3
95.	Dolomite, coarsely crystalline, upper mottled, lower structureless, dark-grey, weathering dark grey, one bed. Weathered surface friable and vuggy.	3.3	595.5
94.	Dolomite, finely crystalline, laminated, laminae near base ripple marked, light-grey, weathering light grey, 1- to 4-inch bedded.	1.0	592.2
93.	Dolomite, medium to coarsely crystalline, structureless, few beds laminated, laminae yellowish-brown argillaceous material, medium-grey, weathering medium grey, 3- to 9-inch bedded. Brown argillaceous material common along bedding surfaces.	3.0	591.2
92.	Dolomite, medium crystalline, upper mottled, lower banded, medium-grey, one bed.	1.2	588.2

Unit	Lithologic description	Thickness (feet) Unit	Total
91.	Dolomite, intercalated medium-crystalline laminated and coarsely crystalline structureless, dark-grey, weathering dark grey, 2- to 4-inch bedded. Vugs common.	3.0	587.0
90.	Dolomite, finely crystalline, laminated, laminae irregular discontinuous concentrations of yellowish-brown argillaceous material, medium-grey, weathering light medium grey, 1- to 6-inch bedded. Vugs partly filled with white crystalline dolomite common on weathered surface.	1.8	584.6
89.	Dolomite, finely to medium crystalline, structureless, medium-grey, weathering medium dark grey, 2-inch to 1-foot bedded.	2.4	582.2
	Thickness of Shoenberger Member		530.2
	Forge Union Member		
88.	Dolomite, sandy, finely crystalline, laminated and banded, laminae due to sand-size quartz grains and more coarsely crystalline dolomite, light-grey, weathering light grey, one bed.	1.2	579.8
87.	Dolomite, medium-crystalline, mottled light grey, parts faintly laminated, medium-grey, weathering medium grey. Vugs common near base.	6.3	578.6
86.	Dolomite, finely crystalline, laminated and banded, parts structureless, light-grey, weathering light grey, 6-inch bedded.	2.5	572.3
85.	Dolomite, coarsely crystalline, mottled by light-grey finely crystalline dolomite, oolitic, medium-grey, weathering dark grey, 6-inch to 1-foot bedded. *Lecanospira* molds rare.	2.5	569.8
84.	Dolomite, sandy, finely crystalline, laminated, light-grey, weathering light grey. Some sand-size quartz grains throughout.	3.3	567.3
83.	Dolomite, coarsely crystalline, mottled, oolitic, dark-grey, weathering dark grey. Solution cavities common on weathered surface. *Lecanospira* molds common. Six- to 9-inch transition zone with overlying unit.	3.3	564.0
82.	Dolomite, finely crystalline, laminated, some laminae slumped and irregular, light-grey, weathering light grey.	4.1	560.7
81.	Dolomite, coarsely crystalline, mottled, oolitic, dark-grey, weathering dark grey, 6-inch to 1½-foot bedded. Vugs common. *Lecanospira* molds common.	16.6	556.6
80.	Dolomite, sandy, finely crystalline, laminated, laminae due to sand-size quartz grains and color differences, light-grey, weathering light grey, one bed.	3.8	540.0
79.	Dolomite, finely crystalline, laminated and banded, laminae layers of medium-crystalline dolomite, medium-grey, weathering medium grey.	3.2	536.2

Unit	Lithologic description	Thickness (feet) Unit	Thickness (feet) Total
78.	Dolomite, coarsely crystalline, mottled, dolorudite, upper 2 feet oolitic, dark-grey, weathering dark grey, 4-inch to 1-foot bedded. *Lecanospira* common.	8.2	533.0
77.	Dolomite, sandy, finely to medium crystalline, upper laminated, laminae irregular, lower structureless, medium-grey, weathering light grey, 1-inch to 1-foot bedded. Sand-size quartz grains throughout.	1.9	524.8
76.	Dolomite, coarsely crystalline, mottled and streaked by light-grey medium-crystalline dolomite, oolitic, dark-grey, weathering dark grey, 6- to 9-inch bedded. Fetid odor from freshly broken surface. *Lecanospira* molds common.	2.5	522.9
75.	Dolomite, finely crystalline, faintly mottled, parts dolorudite, medium-grey, weathering medium grey, one bed.	2.2	520.4
74.	Dolomite, coarsely crystalline, mottled and streaked by light-grey medium-crystalline dolomite, oolitic, dark-grey, weathering dark grey, 6- to 9-inch bedded. Low-spired gastropod molds rare.	2.8	518.2
73.	Dolomite, finely crystalline, laminated, some laminae irregular or discontinuous, dolorudite upper 2 inches, light-grey, weathering light grey, 3- to 9-inch bedded.	4.1	515.4
72.	Dolomite, medium-crystalline, coarsely crystalline upper 6 inches, mottled light grey, parts dolorudite, medium-grey, weathering medium dark grey. Upper 6 inches friable, solution cavities abundant.	3.4	511.3
71.	Dolomite, finely crystalline, upper banded, lower mottled, light-grey, weathering light grey, 6-inch bedded.	5.4	507.9
70.	Dolomite, medium to coarsely crystalline, mottled by light-grey dolomite, few beds laminated, banded or streaked, middle dolorudite and oolitic, medium-dark-grey, weathering medium dark grey. Vugs common.	5.4	502.5
69.	Dolomite, coarsely crystalline, mottled, dark-grey, weathering dark grey. Low-spired gastropod outlines common.	1.0	497.1
68.	Dolomite, finely crystalline, laminated, parts cross-bedded, lower 6 inches structureless, light-grey, weathering light grey, 9-inch to 1-foot bedded.	3.7	496.1
67.	Dolomite, medium to coarsely crystalline, mottled by light-grey dolomite, dark-grey, weathering dark grey, 1- to 4-inch bedded. Vugs common.	0.7	492.4
66.	Dolomite, finely to medium crystalline, banded light grey, medium-grey, weathering medium grey, 9-inch to 1-foot bedded.	2.7	491.7
65.	Dolomite, cherty, finely to medium crystalline, upper dolorudite, pebbles up to 2 inches long, rest laminated and banded, medium-light-grey, weathering medium grey. Chert nodules, light- to medium-grey, laminated, common near top.	2.0	489.0

Unit	Lithologic description	Thickness (feet) Unit	Total
64.	Dolomite, finely crystalline, well laminated, laminae lower half irregular or cross bedded, light-grey, weathering light grey, 2- to 8-inch bedded. Thin shale interbeds upper 1 foot.	7.5	487.0
63.	Dolomite, medium-crystalline, mottled light brown, medium-grey, weathering medium grey, one bed.	2.7	479.5
62.	Dolomite, finely crystalline, well laminated, medium-grey, weathering light grey, 1-foot bedded.	2.7	476.8
61.	Dolomite, medium-crystalline, mottled, medium-grey, weathering medium grey, one bed.	0.7	474.1
60.	Dolomite, finely crystalline, structureless, medium-light-grey, weathering medium light grey, one bed.	4.7	473.4
59.	Dolomite, medium-crystalline, intercalated mottled or structureless, medium-grey, weathering medium grey, 9-inch to 1½-foot bedded.	5.1	468.7
58.	Dolomite, finely to medium crystalline, structureless, medium-grey, weathering medium grey, 4- to 6-inch bedded.	4.1	463.6
57.	Dolomite, medium-crystalline, upper 1 foot dolorudite, pebbles dark-grey dolomite, rest mottled by light-grey dolomite, medium-grey, weathering medium dark grey. *Lecanospira* abundant near top.	3.0	459.5
56.	Dolomite, medium-crystalline, structureless, dark-grey, weathering medium dark grey. Vugs common.	1.4	456.5
55.	Dolomite, very coarsely crystalline, structureless, dark-grey, weathering dark grey, one bed. Extremely friable.	0.7	455.1
54.	Dolomite, medium-crystalline, laminated and banded, light-medium-grey, weathering light medium grey, 2- to 6-inch bedded.	3.4	454.4
53.	Dolomite, coarsely crystalline, laminated, laminae yellowish-brown, some irregular, medium-dark-grey, weathering medium grey, one bed.	2.7	451.0
52.	Dolomite, medium-crystalline, upper mottled, lower laminated, light-grey, weathering medium grey, one bed. Calcite filled fractures and solution cavities common.	4.8	448.3
51.	Dolomite, medium to coarsely crystalline, upper and lower structureless, middle well laminated and banded, medium-grey, weathering dark grey.	4.8	443.5
50.	Dolomite, medium crystalline, faintly mottled, medium-grey.	5.0	438.7
49.	Dolomite, cherty, coarsely crystalline, structureless, dark-grey, weathering dark grey. Bedded chert, light-grey, dolomoldic, friable, near top.	8.0	433.7
48.	Chert, very-light-grey, dolomoldic, friable, one bed.	0.7	425.7
47.	Dolomite, medium-crystalline, mottled by light-grey dolomite, medium-grey, weathering medium grey.	3.7	425.0
46.	Dolomite, sandy, finely crystalline, well laminated, light-grey, weathering light grey, 2- to 3-inch bedded. Sand-size quartz grains throughout.	3.0	421.3

Unit	Lithologic description	Thickness (feet) Unit	Total
45.	Dolomite, medium-crystalline, dolorudite, pebbles dark-grey dolomite in light-grey dolomite cement, medium-grey, one bed.	0.7	418.3
44.	Dolomite, sandy, finely to medium crystalline, laminated and banded, some irregular or slumped, parts dolorudite, pebblcs dolomite, light- to medium-grey, weathering light grey. Sand-size quartz grains throughout.	5.1	417.6
43.	Dolomite, cherty, coarsely crystalline, mottled, dark-grey, weathering dark grey. Chert abundant lower half.	8.0	412.5
42.	Dolomite, finely crystalline, laminated, medium-grey, weathering medium grey, ¼- to ½-inch bedded.	1.5	404.5
41.	Dolomite, sandy, medium-crystalline, dolorudite, pebbles light-grey dolomite, dark-grey, weathering dark grey. Sand-size quartz grains throughout.	3.0	403.0
40.	Dolomite, finely crystalline, laminated and banded by dark-grey dolomite, medium-grey, weathering medium grey.	1.8	400.0
39.	Dolomite, medium-crystalline, mottled by light-grey dolomite, medium-grey, weathering medium grey.	2.6	398.2
38.	Dolomite, sandy, cherty, finely crystalline, laminated and banded, laminae irregular, light-grey, weathering medium grey. Sand-size quartz grains throughout. Bedded chert, grey, dolomoldic, friable, at top.	3.0	395.6
37.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, dark-grey, weathering medium grey, one bed.	2.2	392.6
36.	Dolomite, sandy, finely crystalline, laminated, sand-size quartz grains along laminae, light-grey, weathering light grey, one bed.	0.7	390.4
35.	Dolomite, very coarsely crystalline, structureless, dark-grey, weathering dark grey, one bed.	1.5	389.7
34.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, one bed.	0.6	388.2
33.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, dark-grey, weathering dark grey, one bed.	0.8	387.6
32.	Dolomite, finely crystalline, upper and lower structureless, middle well laminated, light-grey, weathering light grey.	2.2	386.8
31.	Dolomite, coarsely crystalline, mottled light grey, dark-grey, weathering dark grey, 6-inch bedded. Extremely friable.	2.2	384.6
30.	Dolomite, finely crystalline, laminated and banded, light-grey, weathering light medium grey, 3-inch bedded.	1.0	382.4
29.	Dolomite, coarsely crystalline, mottled and streaked by light-grey dolomite, dark-grey, weathering dark grey, one bed. Extremely friable.	2.0	381.4

Unit	Lithologic description	Thickness (feet) Unit	Total
28.	Dolomite, medium-crystalline, mottled by light-grey dolomite, banded dark grey near middle, medium-grey, weathering medium grey, 3- to 6-inch bedded.	4.4	379.4
27.	Dolomite, coarsely crystalline, mottled, oolitic, oolites dark grey, dark-grey, weathering dark grey.	3.0	375.0
26.	Dolomite, medium-crystalline, mottled, medium-grey, weathering medium grey, one bed.	4.5	372.0
25.	Dolomite, sandy, finely crystalline, laminated and banded, some laminae irregular, sand-size quartz grains along laminae, some bands slumped and contain dolomite pebbles, light-grey, weathering light grey.	5.2	367.5
24.	Dolomite, medium-crystalline, faintly mottled, dark-grey, weathering dark grey, one bed.	0.7	362.3
23.	Dolomite, finely to medium crystalline, upper mottled, lower laminated and banded, medium-grey, weathering light grey, 2- to 6-inch bedded.	4.5	361.6
22.	Dolomite, medium-crystalline, mottled by light-grey coarsely crystalline dolomite, dark-grey, weathering dark grey, one bed. Dolomite-filled solution cavities common.	3.7	357.1
21.	Dolomite, intercalated light-grey, finely crystalline laminated and dark-grey, coarsely crystalline mottled, dolorudite upper 3 inches, pebbles dark-grey dolomite, 2- to 6-inch bedded.	3.7	353.4
20.	Dolomite, medium-crystalline, structureless, dark-grey, weathering dark grey, 9-inch to 1-foot bedded.	4.5	349.7
19.	Dolomite, sandy, finely crystalline, upper 6 inches laminated and banded, rest structureless, light-grey, weathering medium light grey. Sand-size quartz grains throughout. Solution cavities common.	3.7	345.2
18.	Dolomite, cherty, finely crystalline, upper laminated, lower dolorudite, medium-grey dolomite pebbles in light-grey dolomite, light- to medium-grey. Chert nodules, grey, near top. Shale interbeds at top.	1.5	341.5
17.	Dolomite, medium-crystalline, structureless, medium-light-grey, weathering medium grey, 2- to 5-inch bedded.	8.2	340.0
16.	Dolomite, sandy, finely crystalline, laminated and banded, medium-grey, weathering light medium grey. Some sand-size quartz grains throughout.	2.2	331.8
15.	Dolomite, medium-crystalline, structureless, light-grey, weathering medium grey, 1.5-foot bedded. Weathered surface pitted.	3.0	329.6
14.	Dolomite, finely crystalline, laminated and banded, light-grey, weathering light grey, 4- to 6-inch bedded. Some sand-size quartz grains throughout.	1.5	326.6
13.	Dolomite, coarsely crystalline, mottled and streaked by yellowish-brown chert, medium-grey, weathering medium grey, one bed.	3.0	325.1

Unit	Lithologic description	Thickness (feet) Unit	Total
12.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, one bed. Vugs common.	3.0	322.1
11.	Dolomite, medium-crystalline, structureless, some reddish-brown argillaceous streaks, medium-grey, weathering medium grey, 1-inch to 1-foot bedded.	9.7	319.1
10.	Dolomite, cherty, medium to coarsely crystalline, mottled by light-grey dolomite, streaked by argillaceous material, medium-grey, weathering dark grey. Nodular chert, light-grey, dolomoldic, oolitic, oolites light grey, common.	11.1	309.4
9.	Dolomite, finely crystalline, laminated, laminae yellowish-brown, widely spaced, light-grey, weathering light grey, 2- to 4-inch bedded.	2.2	298.3
8.	Dolomite, sandy, cherty, medium crystalline, upper structureless, lower laminated, laminae yellowish-brown argillaceous material and sand-size quartz grains, some quartz sand throughout, medium-light-grey, weathering medium grey. Chert nodules common.	3.7	296.1
7.	Dolomite, sandy, finely crystalline, laminated, light-grey, weathering light medium grey, 1- to 6-inch bedded. Some sand-size quartz grains throughout.	6.7	292.4
6.	Dolomite, sandy, finely crystalline, upper half laminated, some laminae contain sand-size quartz grains, next 4 feet structureless, rest dolorudite, light-grey, weathering light grey.	11.9	285.7
5.	Dolomite, finely crystalline, structureless, light-grey, weathering medium grey. Vugs ¼-inch in diameter.	5.2	273.8
4.	Dolomite, cherty, medium to coarsely crystalline, structureless, medium-dark-grey, weathering dark grey, 6- to 9-inch bedded. Iron-rich chert, yellowish-brown, and oolitic chert abundant, oolites dark and light grey. Extremely friable.	5.9	269.6
3.	Dolomite, finely to medium crystalline, structureless, laminated near top, light-grey, weathering light grey, 1-inch to 2-foot bedded. Yellowish-brown stains common along bedding surfaces.	29.0	262.7
2.	Concealed. Iron-rich chert, reddish-brown, and grey chert abundant.	3.0	233.7
1.	Dolomite, sandy, cherty, finely crystalline, structureless, light-grey, weathering very light grey, 6- to 9-inch bedded. Sand-size quartz grains at top. Bedded chert, irregular, grey, upper 3 inches.	3.7	230.7
	Concealed.	227.0	227.0
	Contact of Nittany Dolomite-Stonehenge Limestone.		
	Thickness of Forge Union Member		579.8
	Thickness of Nittany Dolomite		1220.0

Stonehenge Limestone

Concealed.

SHOENBERGER SECTION

(No. 6)

Approximately 650 feet of the uppermost 860 feet of the Nittany Dolomite are exposed in a road cut along Pennsylvania Highway 350 east of Shoenberger, an abandoned station on the main line of the Pennsylvania Railroad about two miles northwest of Union Furnace, Huntingdon County. In addition, most of the Bellefonte Dolomite and the formations composing the Middle Ordovician limestone sequence are also exposed in this road cut. These exposures are located in the west-central part of the Tyrone 15-minute quadrangle and occur geologically in the northwestern limb of the Scotch Valley syncline.

The lowest exposed beds in the Nittany occur about 275 feet southeast of the intersection of Highway 350 and the road trending northeastwardly from Shoenberger. This intersection is located 17,800 feet east of 78° 15′ west longitude and 12,300 feet south of 40° 40′ north latitude. Southeastwardly from this first exposure, a section made up entirely of dolomite is continuously exposed along the northeast side of Highway 350 to the northwest end of the concrete bridge over the Little Juniata River, a traverse distance of about 2,900 feet. (See Figure 9).

Dolomitic sandstones of the Gatesburg Formation and fossiliferous limestones of the Stonehenge Limestone are exposed about 1,000 feet northeast of the intersection on the northwest side of the road trending northeast. The fossiliferous limestones of the Stonehenge project into a concealed interval directly below the lowest exposure of dolomite in the cut along Highway 350. Lower beds in the Nittany are apparently missing along the highway. Their absence is probably caused by displacements along the Shoenberger fault, whose position is mapped by Butts (1939).

No limestone beds are exposed in the cut between the intersection and the bridge over the Little Juniata River. Thus, the Nittany Dolomite-Bellefonte Dolomite contact is placed at the top of a 200-foot-thick sequence of sandy dolomite beds. Several beds in this sequence contain silicified specimens of *Tritoechia pennsylvanica, Orospira* sp. and oxeakloster sponge spicules. These fossiliferous dolomites occur approximately 1,500 feet southeast of the intersection. The remaining dolomite sequence, extending from the top of the Nittany to the transition zone between the Bellefone Dolomite and the Carlim Limestone, was measured and calculated to be about 1,550 feet thick. This figure corresponds closely to the 1,500 foot thickness reported by Butts (1939) for the Bellefonte in this region. Dolomite beds equivalent in age to the Axemann Limestone may be present in the vicinity of the Nittany-Bellefonte contact.

The sequence of sandy dolomite beds at the top of the Nittany constitute the Etna Furnace Member. The 465 feet of dolomite beds exposed be-

low this sandy sequence make up the Shoenberger Member. The Shoenberger section is designated as the type section for the Shoenberger Member.

After the writer measured and described the Shoenberger section the road bed for Highway 350 was both widened and displaced a short distance to the northeast. The excellent exposures now available are the result of this highway improvement. Nearly all of the intervals in the Nittany that were originally described as concealed are now exposed, but the new cut does not expose any additional units in the concealed interval at the base of the section.

All references to directions and distances are related to the new highway. The section description to follow is a condensation of the writer's original description. The description of beds in the Etna Furnace Member, however, has been modified slightly so that it compares closely with the sequence now exposed in the road cut.

Unit	*Lithologic description*	*Thickness (feet)* *Unit*	*Total*
Bellefonte Dolomite			
	Dolomite, no sand-size quartz grains observed for several hundred feet of section. Units not measured or described.		
Nittany Dolomite			
Etna Furnace Member			
150.	Dolomite, sandy, medium-crystalline, laminated, some sand-size quartz grains concentrated along laminae lower 4 feet, light-grey, weathering light grey, ½- to 5-inch bedded.	10.0	866.6
149.	Dolomite, sandy, coarsely crystalline, intercalated mottled, streaked or laminated, laminae irregular, medium-grey, weathering dark grey, 3-inch to 1-foot bedded. Sand-size quartz grains throughout lower 5 feet.	9.0	856.6
148.	Dolomite, coarsely crystalline, faintly mottled or streaked, medium-grey, weathering medium grey, 6- to 9-inch bedded.	6.8	847.6
147.	Concealed.	3.7	840.8
146.	Dolomite, medium-crystalline, faintly laminated or streaked, medium-grey, weathering dark grey, 6-inch to 2-foot bedded. Vugs coated or filled with light-grey dolomite common.	7.4	837.1
145.	Dolomite, coarsely crystalline, faintly streaked or mottled, dark-grey, weathering dark grey, one bed.	1.6	829.7
144.	Concealed.	2.6	828.1
143.	Dolomite, medium-crystalline, mottled or irregularly laminated, medium-grey, weathering medium light grey, 4-inch to 1-foot bedded. Extremely fractured.	4.2	825.5

Unit	Lithologic description	Thickness (feet) Unit	Total
142.	Dolomite, finely crystalline, laminated, medium-grey, weathering light grey, 6- to 8-inch bedded. Vugs filled by light grey dolomite common.	2.6	821.3
141.	Dolomite, coarsely crystalline, intercalated structureless or streaked, medium-grey, weathering dark grey, 6- to 9-inch bedded.	4.2	818.7
140.	Dolomite, finely to medium crystalline, laminated and banded, laminae near top slumped, light-grey, weathering light grey, 1- to 3-inch bedded.	6.0	814.5
139.	Dolomite, coarsely crystalline, faintly mottled or laminated, laminae irregular, medium-grey, weathering medium grey, 1- to 4-inch bedded.	3.5	808.5
138.	Dolomite, sandy, finely crystalline, laminated and banded, some yellowish-brown streaks, light-grey, weathering light grey, one bed. Some sand-size quartz grains throughout.	1.0	805.0
137.	Dolomite, cherty, medium to coarsely crystalline, laminated, medium-grey, weathering dark grey, 6-inch to 1-foot bedded. Nodular chert, light grey, common near top.	8.0	804.0
136.	Dolomite, sandy, medium-crystalline, laminated and banded, laminae concentrations of sand-size quartz grains, medium-light-grey, weathering light grey, 6- to 9-inch bedded.	3.0	796.0
135.	Dolomite, medium-crystalline, faintly laminated and banded, medium-dark-grey, weathering dark grey, 6-inch to 1-foot bedded.	5.5	793.0
134.	Dolomite, finely crystalline, laminated, medium-grey, weathering light grey, 2- to 5-inch bedded.	2.5	787.5
133.	Dolomite, medium-crystalline, streaked or irregularly laminated, medium-grey, weathering medium grey, 1- to 2-inch bedded.	2.0	785.0
132.	Dolomite, sandy, finely crystalline, laminated, sand-size quartz grains concentrated along laminae and also throughout, medium-light-grey, weathering light grey, ¼-inch to 1-foot bedded.	8.0	783.0
131.	Concealed.	3.0	775.0
130.	Dolomite, coarsely crystalline, mottled, medium-grey, weathering dark grey, 6- to 9-inch bedded.	3.0	772.0
129.	Concealed.	6.0	769.1
128.	Dolomite, sandy, finely crystalline, laminated and banded, sand-size quartz grains concentrated along laminae, light-grey, weathering light grey, ½- to 2-inch bedded.	1.0	763.1
127.	Dolomite, sandy, medium-crystalline, laminated and banded, laminae irregular, some sand-size quartz grains concentrated along laminae and throughout, medium-grey, weathering light grey, 1- to 6-inch bedded.	2.0	762.1

Unit	Lithologic description	Thickness (feet) Unit	Total
126.	Dolomite, coarsely crystalline, mottled or streaked yellowish-brown, dark-grey, weathering dark grey, one bed.	1.0	760.1
125.	Concealed.	7.0	759.1
124.	Dolomite, sandy, medium-crystalline, irregularly laminated or streaked, some sand-size quartz grains concentrated along laminae, medium-grey, weathering dark grey, one bed.	1.0	752.1
123.	Concealed.	4.5	751.1
122.	Dolomite, coarsely crystalline, structureless, black, weathering dark grey, one bed.	1.5	746.6
121.	Dolomite, cherty, finely crystalline, faintly laminated, some laminae irregular, dolorudite near base, medium-grey, weathering light grey, 3-inch to 1-foot bedded. Solution cavities common. Extremely fractured. Nodular chert, light-grey, near top.	5.0	745.1
120.	Dolomite, cherty, coarsely crystalline, streaked by light-grey coarsely crystalline dolomite, medium-grey, weathering medium grey, 3-inch to 1-foot bedded. Nodular chert, medium grey, near base. Extremely fractured. Silicified fragments of *Tritoechia pennsylvanica* common near middle of unit; fragments of *Orospira* sp. rare; oxeakloster sponge spicules common in insoluble residue.	5.0	740.1
119.	Dolomite, sandy, finely crystalline, laminated and banded, abundant sand-size quartz grains concentrated along laminae, meduim-grey, weathering light grey, ½- to 6-inch bedded.		
118.	Dolomite, coarsely crystalline, mottled or streaked light-grey, dolorudite near base, dark-grey, weathering medium grey, 1-inch to 1-foot bedded. Vugs common near top.	6.5	732.1
117.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, 2- to 3-inch bedded.	1.0	725.6
116.	Dolomite, medium-crystalline, mottled, irregularly laminated or banded at top and base, medium-grey, weathering light grey, 4- to 6-inch bedded.	2.0	724.6
115.	Dolomite, cherty, coarsely crystalline, faintly laminated or streaked, upper 4 inches dolorudite, dark-grey, weathering medium grey, 3- to 6-inch bedded. Bedded chert, irregular and discontinuous, near base. Fragments of silicified *Tritoechia pennsylvanica* rare.	1.5	722.6
114.	Dolomite, coarsely crystalline, mottled black, medium-light-grey, weathering medium grey, 3- to 6-inch bedded.	3.0	721.1
113.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, 6-inch bedded. Extremely fractured.	2.5	718.1
112.	Dolomite, sandy, medium to coarsely crystalline, upper		

Unit	Lithologic description	Thickness (feet) Unit	Total
	streaked light grey, lower laminated and banded, some laminae irregular, medium-grey, weathering medium light grey, 2-inch to 1-foot bedded. Some sand-size quartz grains throughout.	2.5	715.6
111.	Concealed.	4.0	713.1
110.	Dolomite, medium to coarsely crystalline, mottled, dark-grey, weathering medium grey, 1-foot bedded.	3.0	709.1
109.	Dolomite, medium crystalline, faintly streaked, streaks yellowish-brown argillaceous material, dark-grey, weathering dark grey, 6-inch bedded.	2.0	706.1
108.	Dolomite, finely crystalline, laminated and banded, laminae faint and slightly irregular, light-grey, weathering light grey, 2- to 4-inch bedded. Solution cavities coated or filled with white coarsely crystalline dolomite common.	1.0	704.1
107.	Concealed.	5.5	703.1
106.	Dolomite, medium-crystalline, faintly laminated, laminae irregular, dark-grey, weathering dark grey, one bed.	5.5	697.6
105.	Dolomite, finely crystalline, banded light and dark grey, bands up to 2 inches thick, some irregular, medium-grey, weathering light medium grey, 1- to 6-inch bedded.	2.0	692.1
104.	Dolomite, cherty, coarsely crystalline, upper irregularly laminated or streaked, laminae layers of brown argillaceous material, lower mottled, dark-grey, weathering medium dark grey, 1- to 3-inch bedded. Nodular chert, black, oolitic, common. Vugs common near base.	4.0	690.1
103.	Concealed.	1.0	686.1
102.	Dolomite, sandy, coarsely crystalline, mottled light grey, medium-grey, weathering medium grey, one bed. Some sand-size quartz grains throughout.	1.5	685.1
101.	Dolomite, sandy, medium-crystalline, upper structureless, lower mottled or streaked by brown argillaceous material, medium-grey, weathering medium dark grey, 3- to 6-inch bedded. Some sand-size quartz grains near top. Oxeakloster sponge spicules common in insoluble residue.	3.1	683.6
	Thickness of Etna Furnace Member		186.1
Shoenberger Member			
100.	Dolomite, medium-crystalline, faintly laminated, laminae widely spaced, light-grey, weathering light grey, one bed.	2.0	680.5
99.	Dolomite, cherty, coarsely crystalline, structureless, few beds faintly mottled or streaked, medium-grey, weathering light grey, 3- to 7-inch bedded. Nodular chert, light grey, near top. Vugs common near base.	3.6	678.5
98.	Dolomite, medium-crystalline, structureless, light-grey, weathering dark grey, one bed.	4.2	674.9

Unit	Lithologic description	Thickness (feet) Unit	Total
97.	Dolomite, medium to coarsely crystalline, mottled, few beds near middle laminated and banded, medium-dark-grey, weathering dark grey, 1-inch to 1-foot bedded. Vugs common near base.	4.7	670.7
96.	Concealed.	2.0	666.0
95.	Dolomite, cherty, upper 1½ feet coarsely crystalline, rest finely crystalline, laminated, medium-light-grey, weathering light grey, 3- to 5-inch bedded. Nodular chert, black, throughout. Vugs filled with quartz crystals common near base.	2.6	664.0
94.	Dolomite, very coarsely crystalline, structureless, medium-grey, weathering dark grey, 1- to 2-foot bedded. Vugs filled with quartz crystals common near base.	4.2	661.4
93.	Dolomite, medium-crystallinc, upper 4 inches faintly streaked, rest mottled, light-medium-grey, weathering medium grey, 2- to 6-inch bedded. Vugs common throughout.	2.0	657.2
92.	Concealed.	1.5	655.2
91.	Dolomite, medium-crystalline, mottled or streaked, light-grey, weathering medium light grey, 6-inch to 1-foot bedded.	3.6	653.7
90.	Concealed.	5.8	650.1
89.	Dolomite, cherty, coarsely crystalline, faintly mottled or streaked, oolitic lower 3 inches, dark-grey, weathering medium grey, one bed. Nodular chert, oolitic, near base.	2.0	644.3
88.	Dolomite, finely crystalline, laminated and banded, light-grey, weathering light grey, 2- to 3-inch bedded.	1.0	642.3
87.	Dolomite, coarsely crystalline, mottled, light-grey, weathering medium grey, 4- to 6-inch bedded.	1.5	641.3
86.	Concealed.	12.6	639.8
85.	Dolomite, coarsely crystalline, upper 3 feet mottled, rest laminated, medium-dark-grey, weathering medium grey, 4-inch to 1-foot bedded. Vugs coated or filled with light-grey coarsely crystalline dolomite common.	5.0	627.2
84.	Concealed.	5.6	622.2
83.	Dolomite, medium-crystalline, upper structureless, lower laminated, some laminae irregular, light-grey, weathering light grey, 3-inch to 2-foot bedded. Solution cavities common near middle.	11.5	616.6
82.	Dolomite, cherty, finely to medium crystalline, intercalated structureless or faintly laminated, medium-grey, weathering light grey, 1- to 3-inch bedded. Bedded chert, black, ¼ inch thick, discontinuous, at top.	6.3	605.1
81.	Dolomite, coarsely crystalline, upper mottled, lower faintly laminated, dolorudite near base, medium-dark-grey, weathering dark grey, 6-inch to 2-foot bedded. Vugs common near base.	7.8	598.8

Unit	Lithologic description	Thickness (feet) Unit	Total
80.	Concealed.	3.1	591.0
79.	Dolomite, medium-crystalline, faintly laminated, medium-dark-grey, weathering dark grey, 4- to 6-inch bedded. Vugs common.	3.1	587.9
78.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, one bed.	1.0	584.8
77.	Concealed.	5.2	583.8
76.	Dolomite, coarsely crystalline, structureless, dark-grey, weathering dark grey, 1- to 4-inch bedded. Unit fractured; fractures filled with white crystalline dolomite.	6.3	578.6
75.	Dolomite, medium-crystalline, laminated, laminae irregular and layers of argillaceous material, medium-light-grey, weathering dark grey, 1- to 6-inch bedded.	1.6	572.3
74.	Dolomite, finely crystalline, laminated, some laminae irregular, medium-grey, weathering light grey, 2-inch to 1-foot bedded.	10.2	570.7
73.	Dolomite, medium to coarsely crystalline, structureless, medium-grey, weathering dark grey, one bed.	1.4	560.5
72.	Dolomite, finely crystalline, laminated and banded, dolorudite lower 2 feet, medium-light-grey, weathering light grey, 6-inch to 1-foot bedded.	4.0	559.1
71.	Dolomite, medium-crystalline, irregularly laminated or streaked, light-grey, weathering medium grey, 1- to 2-inch bedded.	2.2	555.1
70.	Dolomite, finely to medium crystalline, faintly laminated, dark-grey, weathering medium grey, one bed.	1.6	552.9
69.	Dolomite, very coarsely crystalline, upper structureless, lower streaked yellowish-brown, medium-dark-grey, weathering dark grey, 2- to 6-inch bedded.	3.8	551.3
68.	Dolomite, finely to medium crystalline, laminated, dolorudite near base, medium-light-grey, weathering light grey, 1- to 9-inch bedded.	6.3	547.5
67.	Concealed.	5.8	541.2
66.	Dolomite, medium-crystalline, streaked or faintly laminated, light-grey, weathering light grey, 1-foot bedded. Vugs coated or filled with light-grey crystalline dolomite abundant.	2.0	535.4
65.	Dolomite, finely crystalline, structureless, black, weathering medium grey, ½- to 3-inch bedded.	3.2	533.4
64.	Concealed.	2.6	530.2
63.	Dolomite, medium-crystalline, intercalated laminated or streaked, medium-grey, weathering light grey, 2- to 6-inch bedded. Extremely fractured near base.	4.1	527.6
62.	Concealed.	1.6	523.5
61.	Dolomite, finely to medium crystalline, upper 3 feet mottled or streaked, rest laminated, some laminae irregular or cross-bedded, medium-grey, weathering medium light grey, 2-inch to 1-foot bedded.	7.0	521.9

Unit	Lithologic description	Thickness (feet) Unit	Total
60.	Dolomite, coarsely crystalline, laminated, laminae irregular and colored yellowish-brown to black, dark-grey, weathering dark grey, one bed.	1.0	514.9
59.	Dolomite, finely crystalline, intercalcated structureless and faintly laminated, dark-grey, weathering medium grey, 2- to 3-inch bedded.	2.1	513.9
58.	Concealed.	2.6	511.8
57.	Dolomite, medium-crystalline, laminated, some laminae irregular, medium-grey, weathering light grey, 1- to 5-inch bedded.	3.7	509.2
56.	Dolomite, coarsely crystalline, faintly streaked or laminated, laminae irregular, medium-grey, weathering dark grey, 1- to 4-inch bedded. Thin shale beds common near base.	3.6	505.5
55.	Dolomite, medium-crystalline, laminated, few beds near base streaked, some laminae irregular, medium-grey, weathering light grey, 2-inch to 1-foot bedded. Vugs filled by light-grey chert common near base.	6.2	501.9
54.	Dolomite, cherty, medium to coarsely crystalline, upper streaked, lower laminated, medium-grey, weathering light medium grey, 4-inch to 2-foot bedded. Bedded chert, black, 1-inch thick, near middle.	6.0	495.7
53.	Dolomite, cherty, medium-crystalline, structureless, medium-grey, weathering light medium grey, 6-inch to 2-foot bedded. Nodular chert, black, near top. Vugs coated or filled with light-grey chert common.	9.0	489.7
52.	Dolomite, coarsely crystalline, upper faintly laminated, laminae irregular, lower structureless, few beds near base laminated, medium-grey, weathering medium dark grey, 6-inch to 1½-foot bedded.	6.0	480.7
51.	Concealed.	2.0	474.7
50.	Dolomite, medium to coarsely crystalline, intercalated structureless and streaked or laminated, laminae irregular, medium-dark-grey, weathering dark grey, 2-inch to 1-foot bedded.	3.5	472.7
49.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, one bed.	1.5	469.2
48.	Dolomite, finely to medium crystalline, upper mottled or streaked, lower laminated, medium-grey, weathering medium light grey, 2-foot bedded.	4.0	467.7
47.	Concealed.	5.5	463.7
46.	Dolomite, finely crystalline, laminated, medium-grey, weathering light grey, one bed.	1.5	458.2
45.	Concealed.	52.6	456.7
44.	Dolomite, medium-crystalline, structureless, dark-grey, weathering dark grey, 2- to 6-inch bedded.	1.4	404.1
43.	Concealed.		
42.	Dolomite, cherty, finely to medium crystalline, lam-		

Unit	Lithologic description	Thickness (feet) Unit	Total
	inated, medium-grey, weathering medium light grey, 2- to 6-inch bedded. Nodular chert, black, common near base.	3.4	396.5
41.	Dolomite, coarsely crystalline, structureless, black, weathering dark-grey, 9-inch to 1-foot bedded.	2.8	393.1
40.	Concealed.	10.2	390.3
39.	Dolomite, coarsely crystalline, structureless, light-grey, weathering medium grey, one bed.	1.5	380.1
38.	Dolomite, finely crystalline, laminated, brownish-grey, weathering light grey, one bed.	2.8	378.6
37.	Dolomite, cherty, coarsely crystalline, structureless, medium-dark-grey, weathering light grey, 1-foot bedded. Irregularly-shaped patches of white chert common.	3.0	375.8
36.	Concealed.	8.5	372.8
35.	Dolomite, medium-crystalline, streaked yellowish to dark brown, medium-grey, weathering medium grey, one bed.	3.8	364.3
34.	Dolomite, medium to coarsely crystalline, structureless, dark-grey, weathering dark grey, 2- to 9-inch bedded. Vugs coated or filled by light-grey crystalline dolomite common. Unit extremely fractured.	5.2	360.5
33.	Concealed.	12.8	355.3
32.	Dolomite, medium to coarsely crystalline, intercalated structureless or laminated, laminae irregular, few beds dolorudite, dolomite pebbles cemented by light-grey dolomite cement, dark-grey, weathering medium grey, 1- to 3-inch bedded. Extremely fractured.	1.0	342.5
31.	Dolomite, finely crystalline, laminated or mottled black, some laminae irregular, light-grey, weathering light grey, 2- to 6-inch bedded.	2.0	341.5
30.	Concealed.	3.4	339.5
29.	Dolomite, cherty, coarsely crystalline, structureless, dark-grey, weathering dark grey, one bed. Nodular chert, black, near top. Vugs coated or filled by light-grey coarsely crystalline dolomite common.	3.0	336.1
28.	Dolomite, finely to medium crystalline, intercalated laminated or structureless, dark-grey, weathering medium grey, 2- to 3-inch bedded.	3.0	333.1
27.	Dolomite, coarsely crystalline, structureless, few beds faintly laminated or streaked, light-grey, weathering medium grey, 9-inch to 1½-foot bedded.	3.9	330.1
26.	Concealed.	36.1	326.2
25.	Dolomite, medium-crystalline, streaked, medium-grey, weathering medium grey, one bed.	1.0	290.1
24.	Concealed.	4.1	289.1
23.	Dolomite, coarsely crystalline, mottled and streaked by light-grey crystalline dolomite, dark-grey, weathering dark grey, one bed.	0.5	285.0

Unit	Lithologic description	Thickness (feet) Unit	Total
22.	Concealed.	14.0	284.5
21.	Dolomite, coarsely crystalline, streaked yellowish-brown, medium-grey, weathering light grey, 4- to 6-inch bedded.	2.0	270.5
20.	Concealed.	2.1	268.5
19.	Dolomite, finely crystalline, laminated, medium-grey, weathering light grey, 2-inch bedded.	1.1	266.4
18.	Dolomite, medium-crystalline, laminated or streaked yellowish-brown, laminae irregular, dark-grey, weathering medium grey, 1- to 4-inch bedded.	1.4	265.3
17.	Dolomite, coarsely crystalline, structureless, dark-grey, weathering dark grey, one bed.	3.3	263.9
16.	Dolomite, finely to medium crystalline, laminated, light-grey, weathering light grey, 2- to 6-inch bedded. Extremely fractured.	3.0	260.6
15.	Concealed.	4.6	257.6
14.	Dolomite, coarsely crystalline, intercalated mottled or structureless, black, weathering light grey, 6- to 9-inch bedded.	1.7	253.0
13.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, 2- to 3-inch bedded.	2.1	251.3
12.	Dolomite, medium to coarsely crystalline, structureless, medium-grey, weathering dark grey, one bed.	2.5	249.2
11.	Dolomite, finely to medium crystalline, laminated or streaked, some laminae irregular, medium-grey, weathering light grey, 2- to 6-inch bedded. Extremely fractured.	2.1	246.7
10.	Dolomite, medium to coarsely crystalline, faintly laminated or streaked, black to dark-grey, weathering dark grey, 2- to 6-inch bedded. Vugs common. Extremely fractured.	5.5	244.6
9.	Dolomite, finely to medium crystalline, laminated, medium-grey, weathering light grey, 2- to 6-inch bedded. Extremely fractured.	3.8	239.1
8.	Dolomite, medium-crystalline, mottled or streaked yellowish-brown, streaks concentrations of argillaceous material, dark-grey, weathering dark grey, 6-inch to 2-foot bedded.	2.5	235.3
7.	Dolomite, finely to medium crystalline, laminated, meium-grey, weathering light grey, 4-inch to 1-foot bedded.	3.8	232.8
6.	Dolomite, medium-crystalline, faintly laminated, few beds in part oolitic, medium-to dark-grey, weathering medium grey, 3- to 6-inch bedded.	4.7	229.0
5.	Dolomite, finely to medium crystalline, laminated, light-to medium-grey, weathering light grey, 6-inch to 1½-foot bedded.	2.5	224.3

Unit	Lithologic description	Thickness (feet) Unit	Total
4.	Dolomite, medium-crystalline, intercalated structureless or faintly streaked, dark-grey, weathering medium grey, 1- to 4-inch bedded. Extremely fractured.	3.0	221.8
3.	Dolomite, finely crystalline, laminated, medium-grey, weathering medium grey, 1- to 3-inch bedded.	3.0	218.8
	Exposed thickness of Shoenberger Member		464.7
2.	Concealed. Beds of Stonehenge Limestone, located approximately 1,000 feet northeast of traverse along road heading northeast from Shoenberger, project into middle of concealed interval.	139.1	215.8
1.	Poorly exposed interval. Some scattered exposures of dolomite.	76.7	
	Exposed thickness of Nittany Dolomite		866.6
Shoenberger Fault			
Gatesburg Dolomite			
	Concealed. Some oolitic chert float.	91.0	
	Dolomite, coarsely crystalline, mottled, oolitic, dark-grey, weathering dark grey. Oolitic chert float abundant. Sandstone float, extremely friable, common. Interval not measured.		

MOUNT ETNA SECTION

(No. 8)

The Nittany Dolomite is well exposed three-tenths of a mile north of Mount Etna, Blair County. The exposures are located in the southwestern part of the Tyrone 15-minute quadrangle, and occur geologically in the southeastern limb of an unnamed anticline. The section was measured along a traverse that begins about 500 feet northwest of a stone farm house located 19,100 feet east of 78° 15′ west longitude and 9,000 feet north of 40° 30′ north latitude, then moves along the north side of Roaring Run to the road paralleling the Frankstown Branch of the Juniata River, continues northeastwardly along this road, and ends at the point where the road turns northward away from the river, 1,400 feet west of 78° 10′ west longitude and 9,200 feet north of 40° 30′ north latitude. Beds in the upper part of the underlying Larke Dolomite and in the lower half of the Nittany Dolomite range in strike from N. 30° E. to N. 45° E.; dip ranges from 28° to 44° SE. In the upper half of the Nittany strike values range from N. 22° E. to N. 32° E. and dip ranges from 37° to 42° SE. (See Figure 9).

The Nittany Dolomite-Larke Dolomite contact is located about 200 feet N. 50° W. from the most westerly exposure in a low cliff located about 100 feet west of the wooden house directly up slope from the Etna Furnace. At this locality it occurs at the top of a concealed interval that overlies a bed of dark-grey, coarsely crystalline, mottled and streaked dolomite containing silicified fragments of *Finkelnburgia* cf. *F. virginica, Lytospira*? *multiseptarius, Ophileta* sp., *Ribeiria* cf. *R. parva,* and type III amphineuroid plates. The base of the Nittany Dolomite occurs approximately 100 feet stratigraphically above the highest limestone bed found in the Larke Dolomite.

The top of the Nittany Dolomite is located below the first limestone bed encountered in the Axemann Limestone.

The Mount Etna section, on the whole, is one of the most complete sections measured and described by the writer. This section is designated as the type section for the Etna Furnace Member.

Unit	*Lithologic description*	*Thickness (feet)* *Unit*	*Total*
Axemann Limestone			
	Limestone, not measured or described.		
	Concealed. Axemann Limestone-Nittany Dolomite contact placed at base of interval.	12.3	

Unit	Lithologic description	Thickness (feet) Unit	Total
Nittany Dolomite			
Etna Furnace Member			
189.	Dolomite, medium-crystalline, upper structureless, lower mottled medium grey, medium-dark-grey, weathering medium grey, 2-inch to 1-foot bedded. Silicified forms resembling crinoid plates common near middle of unit.	3.1	1099.5
188.	Dolomite, coarsely crystalline, intercalated structureless or streaked light grey, dark-grey, weathering dark grey, 1- to 3-inch bedded. Dolomitized *Ophileta* cf. *O. solida* common; silicified long, thin, high-spired gastropods rare.	5.0	1096.4
187.	Dolomite, coarsely crystalline, dolorudite, pebbles dark grey, cemented by light-grey coarsely crystalline dolomite, dark-grey, weathering dark grey, 1- to 4-inch bedded.	6.2	1091.4
186.	Dolomite, very coarsely crystalline, intercalated structureless or streaked, medium-grey, weathering medium dark grey, 2- to 4-inch bedded.	2.3	1085.2
185.	Dolomite, finely crystalline, laminated and banded, laminae light and medium grey, middle 3 feet medium crystalline and structureless, medium-grey, weathering medium light grey, ¼- to 4-inch bedded. Vugs coated with crystalline dolomite common near base.	6.0	1082.9
184.	Dolomite, coarsely crystalline, structureless, medium-grey, weathering medium dark grey, 2- to 8-inch bedded. Extremely fractured upper 3 feet.	3.8	1076.9
183.	Dolomite, finely crystalline, structureless, medium-grey, weathering medium grey, 1- to 3-inch bedded. Solution cavities common near top.	1.3	1073.1
182.	Dolomite, coarsely crystalline, upper mottled and streaked by light-grey dolomite, lower laminated, medium-dark-grey, weathering dark grey, 1- to 4-inch bedded.	1.7	1071.8
181.	Dolomite, finely crystalline, laminated and banded, some laminae irregular, medium-light-grey, weathering light grey, 2- to 6-inch bedded.	1.3	1070.1
180.	Dolomite, coarsely crystalline, streaked by light-grey dolomite, medium-dark-grey, weathering dark grey, ½- to 3-inch bedded. Shale bed, 1 inch thick, 1 foot below top.	2.5	1068.8
179.	Dolomite, upper finely crystalline and structureless, lower coarsely crystalline and faintly mottled by light-grey dolomite, medium-dark-grey, weathering dark grey, 1- to 6-inch bedded.	1.6	1066.3
178.	Dolomite, finely crystalline, upper faintly laminated, lower structureless, medium-grey, weathering light grey, 2- to 4-inch bedded. Shale bed, 1 inch thick, at top.	2.5	1064.7

Unit	Lithologic description	Thickness (feet) Unit	Total
177.	Dolomite, coarsely crystalline, dolorudite, pebbles dark grey in medium-grey dolomite cement, some black argillaceous laminae, dark-grey, weathering dark grey, 2- to 4-inch bedded.	1.7	1062.2
176.	Dolomite, sandy, finely crystalline, laminated, laminae due to color differences and concentrations of sand-size quartz grains, light-grey, weathering light grey, 4- to 6-inch bedded.	1.3	1060.5
175.	Dolomite, intercalated finely and coarsely crystalline, laminated, some coarsely crystalline beds mottled brownish-grey, medium-grey to black, weathering dark grey, 2- to 6-inch bedded. Silicified fragments of *Finkelnburgia* sp. rare.	1.6	1059.2
174.	Dolomite, coarsely crystalline, laminated or streaked, laminae irregular, dark-grey, weathering dark grey, 1- to 4-inch bedded.	2.5	1057.6
173.	Dolomite, very coarsely crystalline, structureless, medium-grey, weathering dark grey, 2- to 4-inch bedded. Silicified fragments of *Diparelasma* sp. rare.	2.1	1055.1
172.	Dolomite, sandy, coarsely crystalline, mottled light grey, parts dolorudite, medium-light-grey, weathering medium grey, 2- to 4-inch bedded. Some sand-size quartz grains throughout. Gastropod outlines rare.	2.1	1053.0
171.	Dolomite, finely crystalline, laminated, laminae due to color and crystal size differences, medium-light-grey, weathering light grey, 3- to 5-inch bedded. Vugs coated with dolomite crystals common.	2.1	1050.9
170.	Dolomite, coarsely to very coarsely crystalline, laminated, laminae irregular layers of argillaceous material, few beds faintly mottled light grey, medium-grey, weathering dark grey, ¼- to 3-inch bedded.	1.3	1048.8
169.	Dolomite, sandy, finely crystalline, upper 7 feet laminated, rest streaked black or structureless, medium-grey, weathering medium light grey, 2- to 6-inch bedded. Some sand-size quartz grains and thin shale beds near top.	11.2	1047.5
168.	Dolomite, finely crystalline, upper 5.5 feet light-grey laminated and banded, laminae due to color and crystal size differences, rest dark-grey and structureless, 2- to 6-inch bedded.	8.8	1036.3
167.	Dolomite, sandy, finely crystalline, laminated and banded, laminae black or due to concentrations of sand-size quartz grains, light-medium-grey, weathering medium light grey, 2-inch to 2-foot bedded. Some sand-size quartz grains throughout upper 5 feet.	8.8	1027.5
166.	Dolomite, coarsely to very coarsely crystalline, upper structureless, lower mottled light grey, dark-grey, weathering dark grey, ½- to 3-inch bedded.	2.5	1018.7

Unit	Lithologic description	Thickness (feet) Unit	Total
165.	Dolomite, medium-crystalline, upper structureless, lower streaked by brown argillaceous material, few beds near base mottled, medium-grey, weathering medium dark grey, 2- to 6-inch bedded. Vugs common upper half.	7.8	1016.2
164.	Dolomite, upper coarsely crystalline and streaked by light-grey dolomite, lower medium-crystalline and mottled, medium-dark-grey, weathering medium dark grey, 3-inch to 1-foot bedded. Vugs common.	7.8	1008.4
163.	Dolomite, finely to medium crystalline, mottled and streaked by medium-grey dolomite, medium-light-grey, weathering medium grey, 2-inch to 2-foot bedded.	8.3	1000.6
162.	Dolomite, cherty, finely crystalline, upper laminated, laminae irregular and discontinuous, lower structureless, upper 2 inches intercalated thin beds of shale and black chert, medium-dark-grey, weathering medium grey, one bed.	2.4	992.3
161.	Dolomite, coarsely crystalline, structureless, dark-grey, weathering medium grey, one bed.	1.0	989.9
160.	Dolomite, cherty, finely crystalline, laminated and banded, medium-light-grey, weathering light grey, ½- to 6-inch bedded. Nodular chert, black, common.	3.9	988.9
159.	Dolomite, sandy, medium to coarsely crystalline, mottled by dark-grey medium-crystalline dolomite, some irregular discontinuous argillaceous laminae, dark-grey, weathering dark grey, 2- to 4-inch bedded. Sand-size quartz grains throughout. Nodular chert, black, and thin shale beds near top.	3.3	985.0
158.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, 2- to 3-inch bedded.	0.9	981.7
157.	Dolomite, medium to coarsely crystalline, faintly mottled and laminated, oolitic, oolites dark grey, medium-dark-grey, weathering medium grey, 2- to 8-inch bedded.	4.2	980.8
156.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, one bed. Vugs coated with dolomite crystals common.	0.9	976.6
155.	Dolomite, cherty, coarsely crystalline, mottled and streaked by light-grey dolomite, oolitic, oolites dark grey, medium-grey, weathering medium dark grey, 1- to 6-inch bedded. Nodular chert, black, near base.	9.4	975.7
154.	Dolomite, medium-crystalline, upper structureless, lower faintly laminated, medium-dark-grey, weathering medium grey, ½- to 4-inch bedded. Vugs coated with dolomite near top. Thin shale beds near base.	1.4	966.3
153.	Dolomite, coarsely crystalline, upper dolorudite, pebbles medium dark grey in light-grey dolomite cement, lower mottled and streaked by light grey finely crystalline dolomite, light-medium-grey, weathering		

Unit	Lithologic description	Thickness (feet) Unit	Total
	medium grey, 4- to 9-inch bedded. Silicified fragments of *Diparelasma* sp. rare upper 1 foot.	2.3	964.9
152.	Dolomite, finely crystalline, mottled by light grey dolomite, medium-light-grey, weathering medium light grey, 2- to 6-inch bedded.	3.3	962.6
151.	Dolomite, medium-crystalline, mottled medium grey, oolitic, oolites dark grey, medium-dark-grey, weathering medium dark grey, 1- to 3-inch bedded.	1.4	959.3
150.	Dolomite, sandy, finely crystalline, banded by layers of sand-size quartz grains, light-grey, weathering light grey, one bed.	1.4	957.9
149.	Dolomite, sandy, coarsely crystalline, mottled by medium-light-grey dolomite, medium-dark-grey, weathering medium dark grey, 3- to 6-inch bedded. Sand-size quartz grains throughout.	1.4	956.5
148.	Dolomite, sandy, finely crystalline, laminated and banded, laminae light grey and slightly irregular, light-grey, weathering medium light grey, 2- to 6-inch bedded. Few sand-size quartz grains throughout.	3.7	955.1
147.	Dolomite, cherty, medium-crystalline, structureless, medium-dark-grey, weathering medium dark grey, 1-inch to 1-foot bedded. Nodular chert, black, common throughout. Upper 2 feet extremely fractured.	9.4	951.4
146.	Dolomite, sandy, finely crystalline, laminated, laminae due to color differences or concentrations of sand-size quartz grains, laminae irregular or slumped, light-grey, weathering light grey, 1- to 6-inch bedded.	3.6	942.0
145.	Dolomite, coarsely crystalline, mottled by light-grey dolomite, oolitic, dark-grey, weathering dark grey, one bed.	1.3	938.4
144.	Dolomite, cherty, finely crystalline, intercalated structureless or faintly laminated, medium-light-grey, weathering medium light grey, 1- to 3-inch bedded. Nodular chert, black, near base.	2.2	937.1
143.	Dolomite, very coarsely crystalline, structureless, parts dolorudite, pebbles dark grey, dark-grey, weathering dark grey, 1- to 6-inch bedded.	2.7	934.9
142.	Dolomite, cherty, finely crystalline, laminated, structureless near base, light-grey, weathering medium light grey, ⅛- to 4-inch bedded. Nodular chert, black, rare. Thin shale interbeds common.	4.0	932.2
141.	Dolomite, sandy, cherty, medium crystalline, mottled and streaked, parts dolorudite, medium-grey, weathering medium grey, 2- to 6-inch bedded. Sand-size quartz grains common in dolomite beds. Irregular patches of black chert common.	1.8	928.2
140.	Dolomite, coarsely crystalline, structureless, medium-grey, weathering medium grey, 2- to 4-inch bedded.	1.3	926.4

Unit	Lithologic description	Thickness (feet) Unit	Total
139.	Dolomite, cherty, medium-crystalline, laminated and banded, medium-light-grey, weathering medium light grey, 3- to 6-inch bedded. Nodular chert, black, throughout.	4.0	925.1
138.	Dolomite, medium to coarsely crystalline, mottled light grey, few beds streaked light grey, medium-grey, weathering light grey, 3-inch to 1-foot bedded.	5.8	921.1
137.	Dolomite, coarsely crystalline, upper 3 feet mottled and dolorudite, rest structureless, medium-grey, weathering medium dark grey, 3- to 6-inch bedded. Sand-size quartz grains common near base.	4.0	915.3
136.	Dolomite, finely crystalline, structureless, middle 2 feet irregularly laminated or streaked by black argillaceous material, light-medium-grey, weathering medium light grey, 2-inch to 1-foot bedded.	6.2	911.3
135.	Dolomite, sandy, cherty, medium to coarsely crystalline, upper structureless, lower streaked by light-grey dolomite, medium-dark-grey, weathering dark grey, 1- to 8-inch bedded. Sand-size quartz grains common near top. Bedded chert, black, irregular and discontinuous, ¼-inch thick, near top. Thin shale beds throughout lower half.	5.4	905.1
134.	Dolomite, sandy, finely crystalline, laminated and banded by concentrations of sand-size quartz grains, medium-grey, weathering medium light grey, ¼- to 2-inch bedded.	2.7	899.7
133.	Dolomite, coarsely crystalline, structureless, few beds mottled or streaked by light-grey dolomite, medium-dark-grey, weathering medium grey, 2- to 6-inch bedded.	6.8	897.0
132.	Dolomite, cherty, medium-crystalline, mottled dark grey, medium-grey, weathering medium grey, 2- to 6-inch bedded. Nodular chert, black, near base.	4.3	890.2
131.	Dolomite, sandy, finely crystalline, laminated and banded, some sand-size quartz grains along laminae, medium-light-grey, weathering medium grey, 2- to 3-inch bedded.	1.3	885.9
130.	Dolomite, very coarsely crystalline, irregularly laminated by yellowish-brown argillaceous material, parts mottled medium grey, medium-light-grey, weathering medium grey, 2- to 4-inch bedded.	2.6	884.6
129.	Dolomite, sandy, cherty, finely crystalline, structureless, few beds faintly laminated, medium-light-grey, weathering medium grey, 2- to 4-inch bedded. Some sand-size quartz grains throughout. Nodular chert, medium-grey, near top. Pyrite crystals throughout.	6.4	882.0
128.	Dolomite, medium-crystalline, streaked by dark-grey argillaceous material, medium-light-grey, weathering medium grey, 3- to 6-inch bedded.	1.3	875.6
127.	Dolomite, coarsely crystalline, streaked yellowish-brown		

Unit	Lithologic description	Thickness (feet) Unit	Total
	or structureless, dark-grey, weathering dark grey, 2- to 6-inch bedded. Vugs coated with light-grey dolomite common.	3.0	874.3
126.	Dolomite, medium-crystalline, mottled medium dark grey, parts oolitic, medium-grey, weathering medium dark grey, 3- to 6-inch bedded. Vugs coated or filled with dolomite and quartz crystals common.	3.0	871.3
125.	Dolomite, sandy, finely crystalline, upper structureless, lower banded due to color differences and concentrations of sand-size quartz grains, medium-grey, weathering medium grey, 2-inch to 1-foot bedded.	4.3	868.3
124.	Dolomite, coarsely crystalline, color mottled, medium-light-grey, weathering medium grey, 3- to 4-inch bedded.	1.7	864.0
123.	Dolomite, medium to coarsely crystalline, upper dolorudite, pebbles dark grey, lower mottled dark grey and streaked yellowish-brown, medium-dark-grey, weathering dark grey, 2- to 4-inch bedded. Thin shale beds throughout.	3.4	862.3
122.	Dolomite, coarsely crystalline, structureless, dark-grey, weathering dark grey, one bed.	1.7	858.9
121.	Dolomite, finely crystalline, mottled light grey and streaked dark grey, medium-grey, weathering medium grey, 3- to 6-inch bedded.	2.6	857.2
120.	Dolomite, medium-crystalline, mottled, lower 3 feet oolitic, medium-dark-grey, weathering medium dark grey, 2- to 6-inch bedded. Some thin shale beds near middle.	4.6	854.6
119.	Dolomite, finely crystalline, streaked by black argillaceous material, medium-light-grey, weathering medium grey, 3- to 6-inch bedded.	1.9	850.0
118.	Dolomite, sandy, medium-crystalline, mottled light grey, medium-grey, weathering medium grey, 6- to 8-inch bedded. Some sand-size quartz grains throughout.	2.4	848.1
117.	Dolomite, coarsely crystalline, upper mottled, lower structureless, medium-grey, weathering dark grey, 6-inch to 1-foot bedded. Vugs lined with quartz crystals common.	2.4	845.7
116.	Dolomite, finely crystalline, structureless, medium-light-grey, weathering medium grey, one bed. Vugs coated with light-grey coarsely crystalline dolomite common.	1.9	843.3
115.	Dolomite, medium-crystalline, oolitic, oolites dark grey, dark-grey, weathering dark grey, ½- to 6-inch bedded. Upper ½ foot thin shale interbeds common.	1.9	841.4
114.	Dolomite, very coarsely crystalline, upper structureless, lower dolorudite, pebbles medium grey in light-grey dolomite cement, medium-grey, weathering medium grey, one bed.	0.9	839.5

Unit	Lithologic description	Thickness (feet) Unit	Total
113.	Dolomite, cherty, finely crystalline, structureless, few beds faintly laminated, medium-grey, weathering medium light grey, 4- to 8-inch bedded. Nodular chert, medium-grey, common near base.	4.7	838.6
112.	Dolomite, finely crystalline, upper 2 feet faintly laminated, rest structureless, light-grey, weathering light grey, 6-inch to 1½-foot bedded. Nodular chert, light- to dark-grey, common near base. Vugs coated by quartz crystals common lower 2 inches.	6.2	833.9
111.	Dolomite, medium-crystalline, upper 3 feet streaked and mottled dark grey, rest banded, bands irregular dark-grey dolomite, light-grey, weathering medium light grey, 1-inch to 1½-foot bedded. Vugs coated or filled with light-grey dolomite common. Some pyrite crystals throughout.	7.6	827.7
110.	Dolomite, finely-crystalline, streaked by yellowish-brown argillaceous material, dark-grey, weathering medium grey, ½- to 1-inch bedded. Thin shale interbeds common.	0.9	820.1
109.	Dolomite, coarsely crystalline, oolitic, oolites dark grey, dark-grey, weathering dark grey, 2- to 4-inch bedded. Silicified small high-spired gastropods rare.	1.9	819.2
108.	Dolomite, very coarsely crystalline, structureless, medium-grey, weathering medium grey, 1- to 2-foot bedded.	3.3	817.3
107.	Dolomite, finely to medium crystalline, mottled light grey, medium-grey, weathering medium grey, 3-inch to 1-foot bedded.	4.7	814.0
106.	Concealed.	1.9	809.3
105.	Dolomite, sandy, medium to coarsely crystalline, upper 5 feet mottled, rest laminated or structureless, light-grey, weathering medium dark grey, 1-inch to 2-foot bedded. Sand-size quartz grains throughout lower 3 feet. Base of Etna Furnace Member placed at base of unit.	8.0	807.4
	Thickness of Etna Furnace Member		303.6
	Shoenberger Member		
104.	Concealed.	3.5	799.4
103.	Dolomite, finely crystalline, structureless, light-grey, weathering medium grey, 1- to 6-inch bedded.	3.0	795.9
102.	Concealed.	12.0	792.9
101.	Dolomite, finely crystalline, faintly laminated or structureless, light-medium-grey, weathering medium grey, 3- to 6-inch bedded.	3.5	780.9
100.	Dolomite, cherty, coarsely crystalline, structureless, medium-dark-grey, weathering dark grey, 3-inch to 1-		

Unit	Lithologic description	Thickness (feet) Unit	Total
	foot bedded. Bedded chert, black, discontinuous, near top and base. Nodular chert, dark-grey, near top.	6.0	777.4
99.	Dolomite, medium-crystalline, streaked or irregularly banded by dark grey, coarsely crystalline dolomite, medium-grey, weathering medium dark grey, 2- to 6-inch bedded. Vugs coated or filled with dolomite common.	10.0	771.4
98.	Dolomite, finely crystalline, laminated, laminae layers of argillaceous material, light-grey, weathering medium grey, 3- to 9-inch bedded.	4.5	761.4
97.	Dolomite, cherty, medium to coarsely crystalline, strucless, dark-grey, weathering dark grey, 9-inch to 1-foot bedded. Nodular chert, black, near top and base.	6.4	756.9
96.	Concealed.	2.8	750.5
95.	Dolomite, finely crystalline, structureless, light-grey, weathering medium light grey, ½- to 6-inch bedded. Vugs coated or filled with dolomite common near top.	5.1	747.7
94.	Dolomite, medium-crystalline, mottled by light-grey dolomite, dolorudite near base, medium-grey, weathering dark grey, 2- to 4-inch bedded.	1.4	742.6
93.	Dolomite, finely crystalline, upper 2 feet structureless, rest laminated, laminae irregular and discontinuous, light-grey, weathering medium grey, 6- to 8-inch bedded. Vugs filled with coarsely crystalline dolomite common near base.	2.8	741.2
92.	Dolomite, coarsely crystalline, mottled light grey, medium-light-grey, weathering dark grey, one bed.	1.4	738.4
91.	Dolomite, finely crystalline, structureless, light-grey, weathering medium grey, 6-inch to 1-foot bedded.	2.3	737.0
90.	Concealed.	4.6	734.7
89.	Dolomite, finely crystalline, structureless, few beds faintly laminated, light-grey, weathering medium grey, 2- to 9-inch bedded.	3.2	730.1
88.	Concealed.	12.9	726.9
87.	Dolomite, cherty, finely crystalline, structureless, few beds near base laminated, light-medium-grey, weathering medium grey, 2-inch to 1-foot bedded. Irregularly-shaped, medium grey chert common near top. Vugs coated by light-grey dolomite common upper half.	8.5	714.0
86.	Dolomite, cherty, finely crystalline, interbedded light-grey laminated and medium-grey structureless, 2- to 6-inch bedded. Bedded chert, black, 1- to 6-inches thick, at top.	7.0	705.5
85.	Dolomite, medium-crystalline, structureless, few beds near base streaked, dark-grey, weathering medium dark grey, 1-inch to 1-foot bedded. Vugs coated or filled with dolomite near top.	3.0	698.5
84.	Dolomite, finely crystalline, laminated, medium-light-grey, weathering medium light grey, 6-inch to 1½-foot bedded.	4.0	695.5

Unit	Lithologic description	Thickness (feet) Unit	Total
83.	Dolomite, medium-crystalline, structureless, medium-grey, weathering medium grey, 3- to 6-inch bedded.	2.0	691.5
82.	Concealed.	103.4	689.5
81.	Dolomite, coarsely crystalline, streaked light grey, dark-grey, weathering medium grey, 3-inch to 1-foot bedded.	2.0	586.1
80.	Concealed.	10.5	584.1
79.	Dolomite, medium to coarsely crystalline, mottled medium grey, lower 3½ feet streaked by light-grey dolomite, medium-dark-grey, weathering medium grey, 6-inch to 1½-foot bedded.	6.5	573.6
78.	Concealed.	3.1	567.1
77.	Dolomite, coarsely crystalline, mottled and streaked by light-grey medium-crystalline dolomite, dark-grey, weathering medium grey, 1-foot bedded.	2.0	564.0
76.	Concealed.	10.3	562.0
75.	Dolomite, coarsely crystalline, upper structureless, lower mottled by light-grey coarsely crystalline dolomite, few beds streaked yellowish-brown, medium-grey, weathering medium grey, 2- to 6-inch bedded.	6.5	551.7
74.	Dolomite, sandy, finely crystalline, upper 2 feet faintly laminated, rest structureless, few beds mottled and streaked by dark-grey dolomite, medium-light-grey, weathering medium grey, 2- to 6-inch bedded. Some sand-size quartz grains upper 2 feet. Pyrite crystals throughout.	4.5	545.2
73.	Dolomite, sandy, finely crystalline, laminated, laminae layers of dark-grey to black argillaceous material, 1-foot bed near base mottled medium grey and streaked by black argillaceous material, light-medium-grey, weathering medium-grey, 0.1- to 1-foot bedded. Some sand-size quartz grains throughout lower 1 foot. Pyrite crystals throughout.	6.0	540.7
72.	Dolomite, medium-crystalline, mottled or laminated, medium-grey, weathering medium dark grey, 1- to 3-inch bedded. Vugs coated or filled by light grey coarsely crystalline dolomite common.	1.2	534.7
71.	Dolomite, finely crystalline, color laminated, medium-light-grey, weathering medium grey, 2- to 4-inch bedded.	1.6	533.5
70.	Dolomite, medium to coarsely crystalline, upper laminated, laminae irregular black argillaceous layers, lower dolorudite, dark-grey, weathering dark grey, 4- to 6-inch bedded.	2.3	531.9
69.	Dolomite, medium-crystalline, upper 3 feet mottled brownish-grey, rest structureless, light-medium-grey, weathering medium dark grey, 2- to 8-inch bedded. Some vugs coated by light-grey coarsely crystalline dolomite near base.	4.5	529.6
68.	Concealed.	149.4	525.1

Unit	Lithologic description	Thickness (feet) Unit	Total
67.	Dolomite, cherty, finely crystalline, structureless, few beds near top banded medium dark grey, light grey, weathering light grey, one bed. Nodular chert, black, common.	3.2	375.7
66.	Dolomite, medium crystalline, structureless, medium dark grey, weathering dark grey, 2- to 6-inch bedded.	5.1	372.5
65.	Concealed. Base of Shoenberger Member placed 360 feet above base of Nittany Dolomite.	10.3	367.4
	Thickness of Shoenberger Member		435.9
	Forge Union Member		
64.	Dolomite, cherty, coarsely crystalline, few beds medium crystalline, structureless, or mottled and streaked by light-grey coarsely crystalline dolomite, medium-dark-grey, weathering dark grey, 6-inch to 3-foot bedded. Nodules and large irregularly shaped masses of light- to medium-grey chert common.	16.7	357.1
63.	Dolomite, finely crystalline, faintly laminated, light-grey, weathering light grey, one bed.	1.9	340.4
62.	Dolomite, cherty, coarsely crystalline, structureless, medium-dark-grey, weathering dark grey, 4-inch to 1-foot bedded. Nodular chert, medium-dark-grey, common.	8.4	338.5
61.	Dolomite, finely crystalline, laminated and banded, light-grey, weathering light grey, ½- to 4-inch bedded.	5.1	330.1
60.	Dolomite, cherty, coarsely crystalline, streaked by yellowish-brown argillaceous material and light-grey coarsely crystalline dolomite, medium-dark to dark-grey, weathering dark grey, 1- to 3-foot bedded. Chert abundant, as large irregular masses up to 6 feet in diameter or small nodules 1 inch in diameter, colored light pink to dark grey, some dolomoldic. *Leconospira* sp. in chert rare.	10.8	325.0
59.	Dolomite, sandy, cherty, finely crystalline, laminated and banded, laminae in places anastomosing, bands concentrations of sand-size quartz grains, light-grey, weathering light grey, 2-inch to 1-foot bedded. Nodular chert, medium-grey to yellowish-brown, rare.	3.5	314.2
58.	Dolomite, sandy, medium-crystalline, banded by finely crystalline dolomite, dolorudite, pebbles from underlying unit, dark-grey, weathering dark grey, one bed. Sand-size quartz grains abundant throughout.	2.9	310.7
57.	Dolomite, sandy, finely crystalline, laminated and banded by abundant sand-size quartz grains, light-grey, weathering light grey, 2- to 4-inch bedded.	3.5	307.8
56.	Dolomite, finely crystalline, upper structureless, lower laminated by yellowish-brown argillaceous material, me-		

Unit	Lithologic description	Thickness (feet) Unit	Total
	dium-light-grey, weathering medium grey, 4-inch to 1-foot bedded.	5.8	304.3
55.	Dolomite, sandy, coarsely crystalline, structureless, dolorudite near base, pebbles dolomite from underlying unit, dark-grey, weathering dark grey, one bed. Abundant sand-size quartz grains throughout.	1.7	298.5
54.	Dolomite, sandy, finely crystalline, laminated and banded by sand-size quartz grains, light-grey, weathering light grey, 1- to 4-inch bedded.	7.0	296.8
53.	Dolomite, coarsely crystalline, structureless, medium-light-grey, weathering medium grey, 1- to 2-foot bedded.	10.5	289.8
52.	Dolomite, finely crystalline, structureless, light-grey, weathering light-grey, 2-inch to 1-foot bedded.	4.9	279.3
51.	Concealed.	4.4	274.4
50.	Dolomite, medium-crystalline, mottled by light-grey coarsely crystalline dolomite and yellowish-brown argillaceous material, medium-dark-grey, weathering medium dark grey, 2- to 6-inch bedded.	4.9	270.0
49.	Dolomite, sandy, finely crystalline, laminated, sand-size quartz grains concentrated into laminae and throughout, color banding common in places, light-grey, weathering light grey, 4- to 6-inch bedded. Some vugs coated with dolomite crystals.	3.9	·265.1
48.	Dolomite, sandy, coarsely, crystalline, structureless, some beds mottled by medium-grey, medium-crystalline dolomite, dark-grey, weathering dark grey, 6-inch to 1-foot bedded. Some sand-size quartz grains throughout.	4.4	261.2
47.	Dolomite, sandy, finely crystalline, laminated and banded, abundant sand-size quartz grains concentrated into laminae, bands and lenses, light-grey, weathering light grey, 2- to 6-inch bedded.	6.8	256.8
46.	Dolomite, sandy, medium-crystalline, mottled by light-grey finely crystalline dolomite, parts dolorudite, medium-dark-grey, weathering dark grey, 4- to 6-inch bedded. Very coarse sand-size quartz grains abundant throughout.	4.9	250.0
45.	Dolomite, medium-crystalline, structureless, light-grey, weathering medium light grey, 9-inch to 1-foot bedded.	2.9	345.1
44.	Dolomite, coarsely crystalline, mottled by brownish-grey medium-crystalline dolomite, some streaks of light-grey coarsely crystalline dolomite, dark-grey, weathering dark grey, 6- to 8-inch bedded.	4.9	242.2
43.	Dolomite, medium-crystalline, upper mottled yellowish-brown, lower structureless, medium-grey, weathering light medium grey, 2- to 6-inch bedded.	5.3	237.3
42.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, 4- to 6-inch bedded.	4.4	232.0

Unit	Lithologic description	Thickness (feet) Unit	Total
41.	Dolomite, medium-crystalline, structureless, light-medium-grey, weathering medium grey, 2- to 4-inch bedded. Large vugs coated or filled with dolomite crystals common.	2.4	227.6
40.	Concealed.	8.8	225.2
39.	Dolomite, sandy, cherty, medium to coarsely crystalline, structureless, oolitic, oolites in nodular chert and dolomite, oolites in light-grey chert colored dark grey, parts dolorudite, pebbles light-grey finely crystalline dolomite, medium-dark-grey, weathering medium dark grey, one bed. Sand-size quartz grains abundant.	2.6	216.4
38.	Concealed.	35.2	213.8
37.	Dolomite, medium-crystalline, mottled by darker grey dolomite, medium-grey, weathering medium dark grey, one bed.	1.7	178.6
36.	Dolomite, cherty, medium to coarsely crystalline, structureless, oolitic, light-medium-grey, weathering medium dark grey, one bed. Nodular chert, light-grey, oolitic, oolites light or medium grey with medium-or dark-grey rims.	2.6	176.9
35.	Concealed.	2.5	174.3
34.	Dolomite, medium-crystalline, structureless, dark-grey, weathering dark grey, one bed.	0.5	171.8
33.	Concealed.	2.4	171.3
32.	Dolomite, finely crystalline, structureless, light-grey, weathering light grey, one bed.	0.9	168.9
31.	Concealed.	2.2	168.0
30.	Dolomite, coarsely crystalline, structureless, medium-grey, weathering medium dark grey, 4-inch to 1-foot bedded.	8.7	165.8
29.	Dolomite, finely crystalline, laminated, light-grey, weathering light grey, one bed.	1.1	157.1
28.	Dolomite, coarsely crystalline, structureless, brownish-grey, weathering dark grey, 2- to 4-inch bedded.	2.0	156.0
27.	Dolomite, medium-crystalline, structureless, few beds streaked yellowish-brown, medium-light-grey, weathering medium grey, 2- to 6-inch bedded. Some vugs filled with dolomite.	6.7	154.0
26.	Dolomite, sandy, finely crystalline, structureless, medium-light-grey, weathering medium light grey, one bed. Some sand-size quartz grains concentrated into lenses and throughout.	1.1	147.3
25.	Dolomite, coarsely crystalline, color mottled yellowish-brown, some argillaceous streaks, medium-grey, weathering medium grey, 2- to 4-inch bedded.	1.4	146.2
24.	Dolomite, sandy, finely crystalline, upper 2 feet irregular laminated and banded, rest structureless, upper 2 feet light grey, rest medium grey, weathering me-		

Unit	Lithologic description	Thickness (feet) Unit	Total
	dium grey, 2-inch to 1½-foot bedded. Sand-size quartz grains abundant upper 3 feet and lower 9 inches, some throughout.	7.0	144.8
23.	Dolomite, sandy, finely crystalline, laminated, some sand-size quartz grains concentrated into laminae and bands lower 2 inches, light-grey, weathering light grey, 4-inch to 1-foot bedded.	5.9	137.8
22.	Dolomite, cherty, medium-crystalline, faintly mottled by darker more coarsely crystalline dolomite, light-medium-grey, weathering medium dark grey, 6-inch to 1-foot bedded. Irregular patches of light-grey chert common.	3.2	131.9
21.	Dolomite, sandy, finely crystalline, laminated and banded, very coarse sand-size quartz grains concentrated into bands lower 6 inches, light-grey, weathering light grey, 4- to 6-inch bedded.	2.7	128.7
20.	Dolomite, finely crystalline, structureless, few beds faintly laminated and banded, laminae slightly irregular, medium-light-grey, weathering light grey, 2- to 6-inch bedded.	4.8	126.0
19.	Dolomite, medium-crystalline, color mottled and streaked by medium-dark-brown argillaceous material, light-brownish-grey, weathering medium grey, 6-inch bedded.	2.7	121.2
18.	Dolomite, finely crystalline, structureless at base and top, rest intercalated laminated, mottled and streaked, medium-light-grey, weathering medium grey, 2-inch to 1-foot bedded.	7.0	118.5
17.	Dolomite, medium-crystalline, faintly mottled by darker grey dolomite, some irregular laminae on weathered surface, light-medium-grey, weathering medium grey, one bed.	2.1	111.5
16.	Dolomite, finely crystalline, structureless, few beds faintly laminated, light-grey, weathering light grey, 6- to 9-inch bedded.	10.8	109.4
15.	Dolomite, sandy, finely crystalline, upper 5 feet laminated and banded, some laminae due to concentrations of sand-size quartz grains, rest structureless, light- to medium-grey, weathering medium light grey, ⅛-inch to 2-foot bedded. Small vugs common.	8.6	98.6
14.	Dolomite, cherty, finely crystalline, laminated, light-medium-grey, weathering light grey, 3- to 4-inch bedded. Nodular chert, medium-grey, common.	1.3	90.0
13.	Dolomite, coarsely crystalline, structureless, medium-dark-grey, weathering medium dark grey, one bed. Solution cavities common. Siliceous debris common on weathered surface.	0.7	88.7
12.	Dolomite, cherty, finely crystalline, upper 1½ feet lami-		

Unit	Lithologic description	Thickness (feet) Unit	Total
	nated and banded, laminae in part cross-bedded, rest structureless, light-grey, weathering light grey, 4-inch to 1-foot bedded. Nodular chert, medium-grey, common near top.	5.0	88.0
11.	Dolomite, medium-crystalline, laminated, laminae yellowish-brown argillaceous material, light-medium-grey, weathering medium grey, 3- to 6-inch bedded.	2.7	83.1
10.	Dolomite, finely crystalline, irregularly mottled by black siliceous material which weathers in relief, some irregular discontinuous laminae, medium-light-grey, weathering light grey, 6-inch to 1-foot bedded.	5.8	80.3
9.	Dolomite, medium-crystalline, mottled and streaked by slightly darker grey dolomite, medium-grey, weathering medium grey, 1- to 3-foot bedded. Weathered surface pitted. Vugs common.	20.6	74.5
8.	Dolomite, finely crystalline, laminated by yellowish-brown material, light-grey, weathering light grey, one bed.	1.6	53.9
7.	Concealed.	22.3	52.3
6.	Dolomite, medium-crystalline, anastomosing streaked or banded by dark-yellowish-brown argillaceous-siliceous material, bands irregular and discontinuous, medium-light-grey, weathering medium grey, one bed. Small vugs common.	2.7	30.0
5.	Dolomite, cherty, coarsely to very coarsely crystalline, some yellowish-brown streaks, light-medium-grey, weathering medium grey, 9-inch to 1-foot bedded. Nodular chert, light-medium-grey, common.	6.4	27.3
4.	Dolomite, finely crystalline, structureless, few beds faintly laminated, medium-grey, weathering medium grey, 1- to 6-inch bedded. Cavities coated or filled with calcite crystals common.	4.8	20.9
3.	Concealed.	7.4	16.1
2.	Dolomite, finely crystalline, faintly streaked and laminated by argillaceous-siliceous material, light-medium-grey, weathering light medium grey, 6-inch to 1-foot bedded. Solution cavities common.	4.4	8.7
1.	Dolomite, coarsely crystalline, mottled by lighter grey dolomite, some yellowish-brown argillaceous streaks, medium-dark-grey, weathering medium dark grey, 2- to 9-inch bedded. Small vugs common.	4.3	
	Thickness of Forge Union Member		360.0
	Thickness of Nittany Dolomite		1099.5

Larke Dolomite

6.	Concealed. Nittany Dolomite-Larke Dolomite contact placed at top of concealed interval.	23.9	147.5

Unit	*Lithologic description*	*Thickness (feet)* *Unit*	*Total*
5.	Dolomite, coarsely crystalline, structureless, parts mottled or streaked by light-grey coarsely crystalline dolomite, dark-grey, weathering dark grey, 1- to 2-foot bedded. Silicified fossil fragments common; forms include *Finkelnburgia* cf. *F. virginica, Lytospira*? *multiseptarius, Ophileta* sp., *Ribeiria* cf. *R. parva,* and type III amphineuroid plates.	3.8	123.6
4.	Concealed.	15.2	119.8
3.	Dolomite, interbedded sequence; finely crystalline laminated or structureless dolomite, and coarsely crystalline mottled, streaked or structureless dolomite. Some laminae due to sand-size quartz grains. Mottled dolomite near top oolitic, oolites dark grey. Unit 2-inch to 2-foot bedded.	51.7	104.6
2.	Limestone, finely to coarsely crystalline, laminated, medium-dark-grey, weathering medium grey, one bed.	1.5	52.9
1.	Dolomite, interbedded sequence; half dark-grey, coarsely crystalline structureless dolomite; one-third concealed; remainder finely crystalline laminated dolomite or medium-crystalline laminated or structureless dolomite. Beds in unit are 3 inches to 2 feet thick.	51.4	

PLATES

PLATE 1.—PHOTOMICROGRAPHS OF MORPHOLOGICAL VARIETIES OF CRYSTALLINE DOLOMITE IN THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X25 for all figures.

Figure 1. Microcrystalline dolomite in a finely crystalline structureless dolomite. Dolomite crystals are irregular shaped, lack rhombohedral faces and are fairly well sorted. Black particles are altered grains of pyrite; larger clear particles are silt-size quartz grains. Average dolomite crystal size about 0.030 mm. Spruce Creek section, 137 feet above base of Nittany Dolomite.

Figure 2. Microcrystalline dolomite in a finely crystalline, laminated dolomite. Laminae due to differences in dolomite crystal size and quartz content. Dark-colored laminae contain very small amounts of silt-size quartz grains, and the average dolomite crystal size is about 0.015 mm. Light-colored laminae contain 10 to 20 percent silt- and very fine sand-size quartz grains, and dolomite crystals average about 0.050 mm. Quartz grains irregular shaped and clear. Rock formed as a graded deposit with coarser grained quartz and dolomite particles settling out first, followed by finer grained dolomite particles. Spring Creek section, 45 feet above base of Nittany Dolomite.

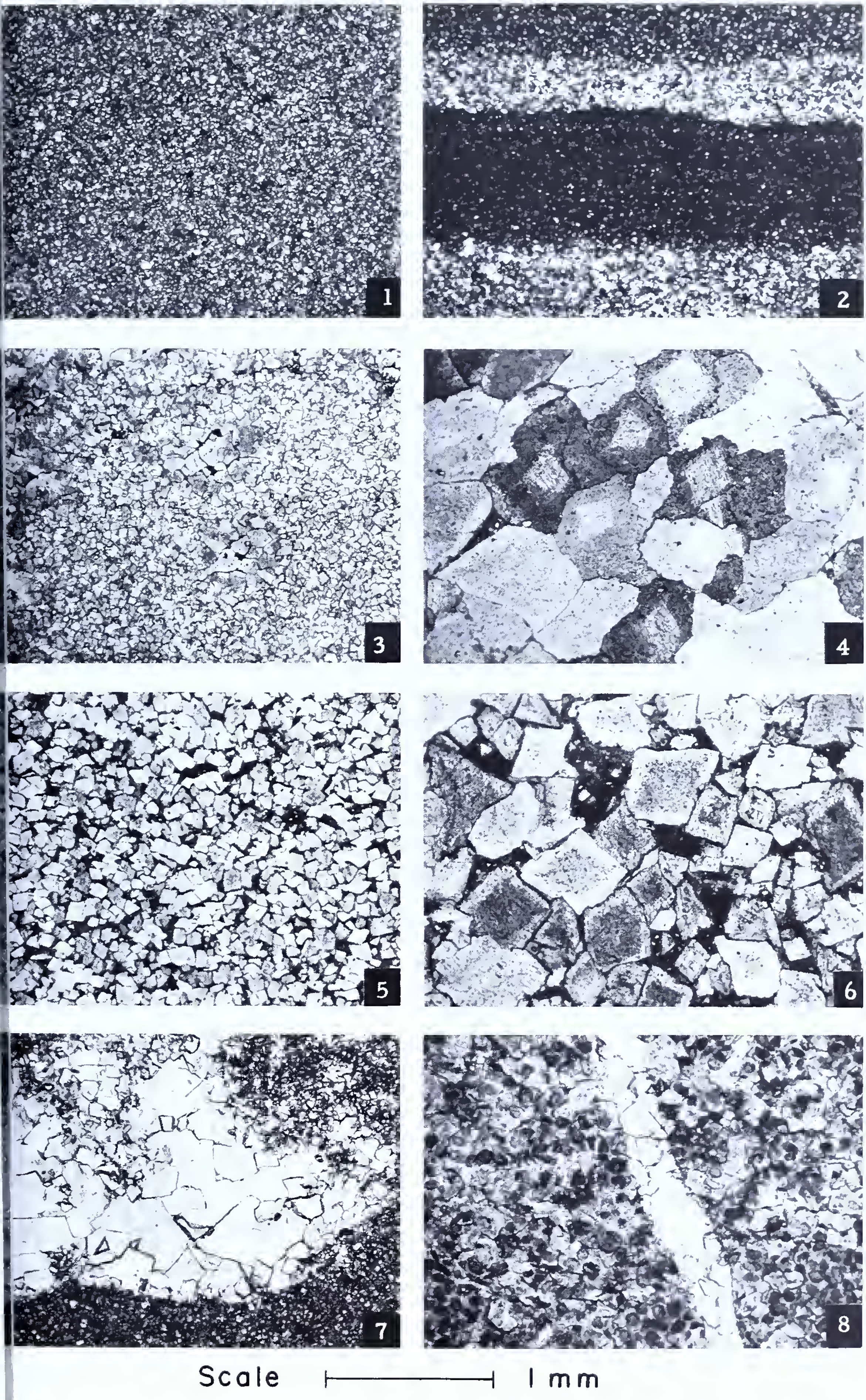
Figure 3. Xenomorphic dolomite in a medium-coarsely crystalline, mottled, oolitic dolomite. Xenomorphic dolomite crystals are relatively large and lack rhombohedral faces. Mottled areas composed of finer dolomite crystals that average about 0.070 mm in diameter. More coarsely crystalline regions are oolites replaced by xenomorphic dolomite crystals that average about 0.12 mm in diameter. Dark areas in oolites caused by interstitial chert that is coated by yellowish-brown material, possibly altered pyrite. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 4. Xenomorphic dolomite in a coarsely crystalline structureless dolomite. Many crystals have a rhombic-shaped nucleus that is surrounded by dolomite in optical continuity with the nucleus, but the final outline of the crystal is irregular. Silt-size quartz grains occur as small, irregular-shaped, colorless particles that are distributed throughout the sample. Minor amounts of interstitial chert occur between crystals. The original sediment possibly was a lime mud that contained minor amounts of larger carbonate particles that recrystallized first, and then altered to dolomite at the same time as the interstitial lime mud. The average dolomite crystal diameter is about 0.35 mm. Waterside section, 300 feet above base of Nittany Dolomite.

Figure 5. Idiomorphic dolomite in a medium-crystalline, laminated dolomite. Dolomite crystals have well-developed rhombic outlines and are moderately well sorted. Dark material between crystals is interstitial chert. The average dolomite crystal diameter is about 0.15 mm. Lutzville section, 675 feet above base of Nittany Dolomite.

Figure 6. Idiomorphic dolomite in a coarsely crystalline structureless dolomite. Many crystals have a darker colored rhombic-shaped nucleus. Dark-colored areas between crystals are composed of interstitial chert. The particles maintained their rhombic outline during transformation to dolomite, possibly by forcing aside or growing into soft siliceous sediments that later solidified as chert. The average dolomite crystal diameter is about 0.40 mm. Spruce Creek section, 192 feet above base of Nittany Dolomite.

Figure 7. Sparry dolomite crystals filling a solution cavity in a finely crystalline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1 mm

PLATE 1.—Continued

dolomite. Most sparry particles have at least one crystal face. Sparry dolomite crystals are commonly clear, sub-rhombic in outline, considerably larger than the dolomite crystals of the host rock, and typically become larger outward from the cavity wall. The largest crystal has a diameter of about 1.0 mm. Mount Etna section, 740 feet above base of Nittany Dolomite.

Figure 8. Sparry dolomite crystals filling a narrow fracture in a medium-crystalline, pelletic dolomite. The largest sparry crystal has a diameter of about 0.5 mm. Shoenberger section, 179 feet below top of Nittany Dolomite.

PLATE 2.—PHOTOMICROGRAPHS ILLUSTRATING DISTRIBUTION OF SILT- AND SAND-SIZE QUARTZ GRAINS IN DOLOMITES OF THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X4.4 for all figures.

Figure 1. Silt-size quartz grains in a finely crystalline, laminated dolomite. The lighter layers contain a larger percentage of quartz grains than do the darker layers. Dolomite crystals in the darker layers average about 0.020 mm in diameter. West Bellefonte section, 540 feet above base of Nittany Dolomite.

Figure 2. Silt- and sand-size quartz grains in a finely crystalline, laminated dolomite. The larger sand grains apparently were the first grains to settle on the surface of sedimentation, and were then moved about by gentle bottom currents and finally trapped in a chamber formed by a burrowing animal. Dolomite crystals within the chamber average about 0.1 mm in diameter, whereas crystals in the surrounding dolomite average about 0.015 mm in diameter. Quartz grains in the chamber range from 0.05 to 0.35 mm in diameter. Shoenberger section, 104 feet below top of Nittany Dolomite.

Figure 3. Rock fragments in a finely crystalline, laminated dolomite. Laminae containing a large percentage of silt-size quartz grains were slumped and broken into fragments that were quickly incorporated into the surrounding fine-grained sediment. Dolomite crystals in the quartz-rich laminae average about 0.050 mm in diameter. Spruce Creek section, 15 feet above base of Nittany Dolomite.

Figure 4. Sand-size quartz grains concentrated into laminae in a finely crystalline dolomite. Sand grains range in diameter from 0.20 to 0.90 mm. Dolomite crystals in underlying lamina average about 0.060 mm in diameter. Spruce Creek section, 181 feet above base of Nittany Dolomite.

Figure 5. Sand-size quartz grains distributed throughout a medium-coarsely crystalline, mottled dolomite. Mottling is caused by irregular shaped patches of coarsely crystalline dolomite. Quartz sand grains range in diameter from 0.065 mm to 0.8 mm, and are distributed throughout the sample. The patchy occurrence of coarsely crystalline dolomite and the absence of sorting of the quartz grains indicate that the original carbonate sediment was being continuously mixed during the time of accumulation. Shoenberger section, 72 feet below top of Nittany Dolomite.

Figure 6. Sand-size quartz grains distributed throughout a medium-coarsely crystalline, mottled, granular dolomite. The dolomite contains carbonate rock fragments and ghosts of particles that may originally have been deposited as oolites. Sand grains range in diameter from 0.15 mm to 0.8 mm. The poor degree of sorting suggests that the original carbonate sediment was being continuously

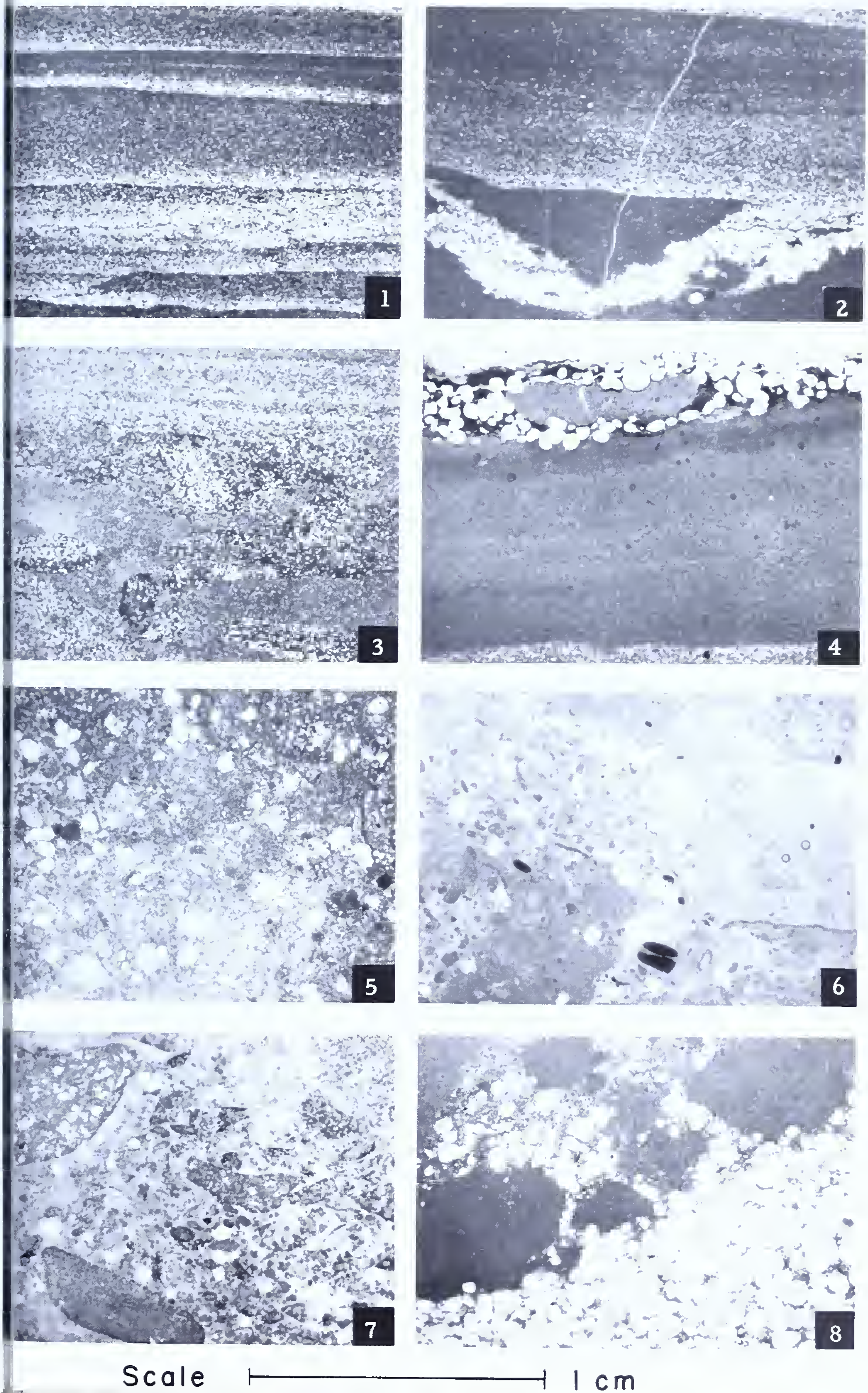
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PLATE 2.—Continued

mixed during the time of accumulation. Spruce Creek section, 210 feet above base of Nittany Dolomite.

Figure 7. Sand-size quartz grains distributed throughout a medium-coarsely crystalline, mottled, granular dolomite. Quartz grains occur in both rock fragments and surrounding dolomite matrix. The margins of carbonate rock fragments are coated by a thin film of dark, argillaceous-siliceous material. Poorly preserved outlines of brachiopods, pelmatozoan plates, and oolites occur throughout the sample. Sand grains range from 0.15 mm to 0.65 mm in diameter. Crystals of dolomite in the interstitial dolomite range from 0.07 mm to 0.15 mm. The sample is very poorly sorted. Waterside section, 807 feet above base of Nittany Dolomite.

Figure 8. Sand-size quartz grains concentrated into bands in finely crystalline dolomite. Sand grains range in diameter from 0.08 mm to 1.0 mm. Dolomite crystals between sand grains average about 0.050 mm in diameter, whereas crystals in the overlying quartz-free layer average about 0.020 mm in diameter. Some quartz grains at the top of the sandy layer were reworked and redeposited within the overlying quartz-free sediment. Spruce Creek section, 233 feet above base of Nittany Dolomite.

PLATE 3.—PHOTOMICROGRAPHS ILLUSTRATING DISTRIBUTION OF SILT- AND SAND-SIZE QUARTZ GRAINS IN DOLOMITES OF THE NITTANY FORMATION

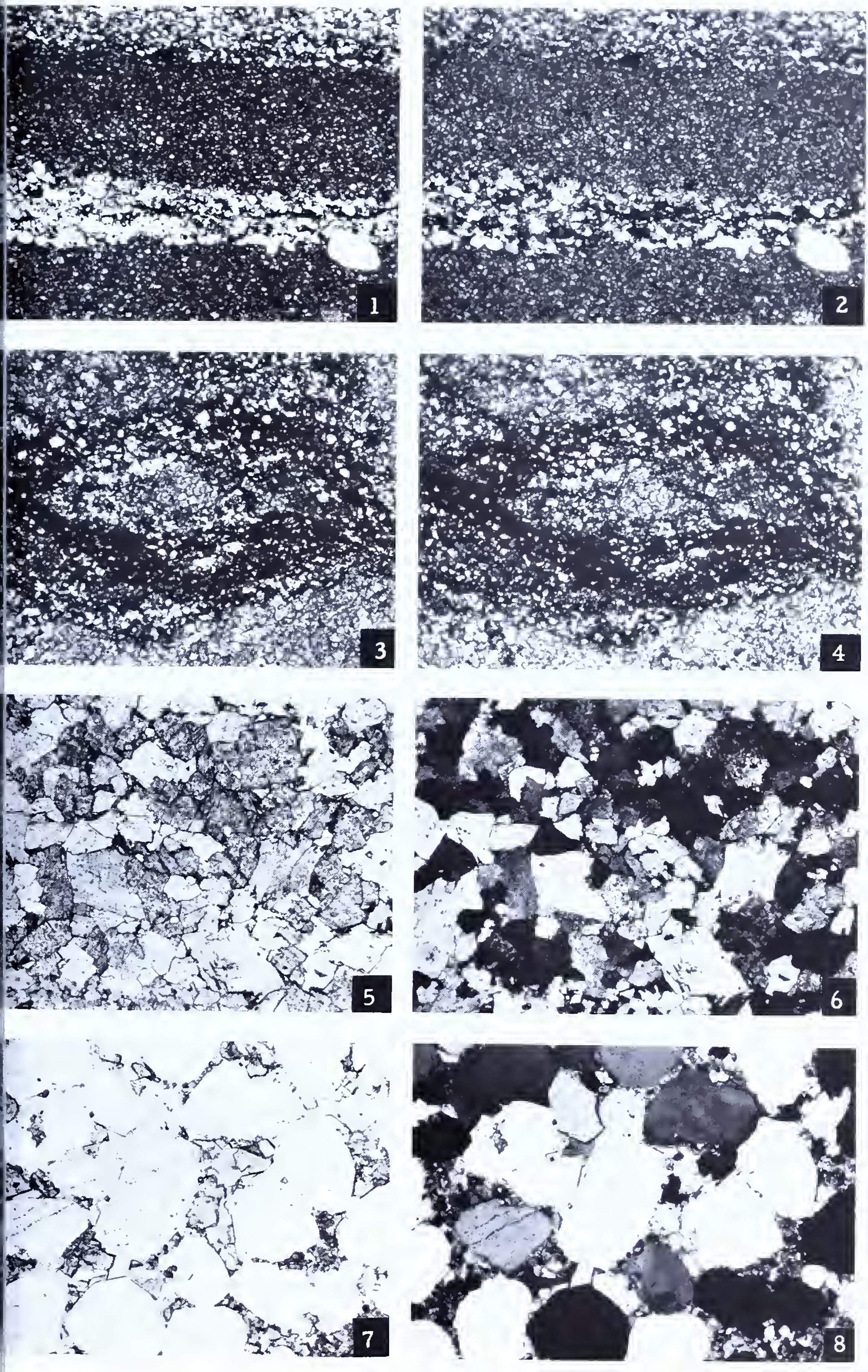
Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X25 for all figures. Odd numbered plates photographed in transmitted light; even numbered plates under crossed nicols.

Figures 1 and 2. Silt- and sand-size quartz grains concentrated as laminae in finely crystalline dolomite. Quartz grains range from 0.04 to 0.35 mm in diameter. A grain of feldspar, possibly microcline, occurs about 1¼ inch to the right of the left margin in the lower quartz-rich lamina (Figure 2). Dolomite crystals in the relatively quartz-free laminae average about 0.015 mm in diameter. West Bellefonte section, 540 feet above base of Nittany Dolomite.

Figures 3 and 4. Silt- and very fine sand-size quartz grains included within dark-brown argillaceous-siliceous streaks in a medium-crystalline, mottled and streaked dolomite. The color of the streaks is due in part to altered disseminated pyrite. Quartz grains range in diameter from 0.03 mm to 0.08 mm. Most dolomite crystals in the sample are xenomorphic but some are idiomorphic; they range in diameter from 0.024 to 0.12 mm. Mount Etna section, 525 feet above base of Nittany Dolomite.

Figures 5 and 6. Silt- and very fine sand-size quartz grains distributed throughout a faintly laminated, coarsely crystalline dolomite. Quartz grains range in diameter from 0.03 mm to 0.09 mm. Dolomite crystals vary from hypidiomorphic to idiomorphic and range in diameter from 0.15 to 0.50 mm. Mount Etna section, 1,071 feet above base of Nittany Dolomite.

Figures 7 and 8. Sand-size quartz grains concentrated in bands in finely crystalline, laminated and banded dolomite. Quartz grains range from 0.08 mm to 1.0 mm in diameter. Many grains have quartz overgrowths in optical continuity with the nucleus. Quartz overgrowths are developed only in regions where quartz grains are tightly packed against one another. Micro fractures that pass through



Scale 1 mm

PLATE 3.—Continued

the grains and continue on into the surrounding overgrowths and adjacent grains probably developed after the sample had become rigid. Dolomite crystals between quartz grains are xenomorphic and average about 0.035 mm in diameter. Spruce Creek section, 233 feet above base of Nittany Dolomite.

PLATE 4.—MASSIVE CHERT IN THE NITTANY DOLOMITE

Thin sections and hand specimen are cut perpendicular to bedding and are oriented with top of section toward top of plate.

Figures 1 and 2. Photomicrographs showing the three varieties of quartz which form massive chert in the Nittany Formation. Microcrystalline quartz forms the bulk of most chert and occurs as an interlocking network of xenomorphic to hypidiomorphic crystals that range from 0.002 to 0.050 in diameter. Chalcedonic quartz has a microscopically fibrous appearance and it is commonly deposited in bands that line the walls of solution cavities. Normal quartz fills cavities and veins in chert and occurs as an interlocking network of xenomorphic to hypidiomorphic crystals ranging from 0.05 to 0.30 mm in diameter. Under crossed nicols (Figure 2) microcrystalline quartz has a speckled appearance and the chalcedonic quartz has a fibrous appearance. Magnification X45. West Bellefonte section, 233 feet above base of Nittany Dolomite.

Figures 3 and 4. Dolomoldic chert. West Bellefonte section, 395 feet above base of Nittany Dolomite.

Figure 3. Molds formed by idiomorphic dolomite crystals on a cut and polished surface of a hand specimen of chert. Magnification X3.

Figure 4. Photomicrograph of dolomoldic chert in transmitted light. Most of the larger idiomorphic dolomite crystals are connected by a network of hairline fractures. The bulk of the sample consists of amorphous silica that possibly developed from microcrystalline quartz that has been leached. Clear silt-size quartz grains occur throughout the amorphous chert. Magnification X30.

Figure 5. Photomicrograph of an oolitic dolomite. The oolites in the upper one-fourth of the figure are nearly totally replaced by microcrystalline quartz, whereas oolites in the rest of the figure have altered to dolomite. Oolites replaced by chert are more perfectly preserved. Magnification X4.4. Spruce Creek section, 185 feet above base of Nittany Dolomite.

Figures 6-8. Photomicrographs of silicified oolites in nodular oolitic chert. Mount Etna section, 215 feet above base of Nittany Dolomite.

Figure 6. Oolites in left half of figure are replaced by chert and are very well preserved. In the right half of the figure the oolites were nearly obliterated during the dolomitization of the original carbonate sediment. The sample also contains sand-size quartz grains and carbonate rock fragments. Magnification X4.4.

Figures 7 and 8. Figure 7 photographed in transmitted light; Figure 8 photographed under crossed nicols. The clear structureless areas in Figure 7 are composed of microcrystalline, chalcedonic and normal quartz; crystalline areas are dolomite. Apparently the oolites were first replaced by silica, which was later replaced by dolomite. Many of the silicified oolites show some of the original concentric structure, but dolomitized oolites preserve only the circular outline. Subsequent dolomitization of the silicified oolite apparently destroys any trace of internal structure. The chert-dolomite distribution in this sample might also occur if silicification and dolomitization are happening at the same time in different parts of the sediment. Magnification X25.

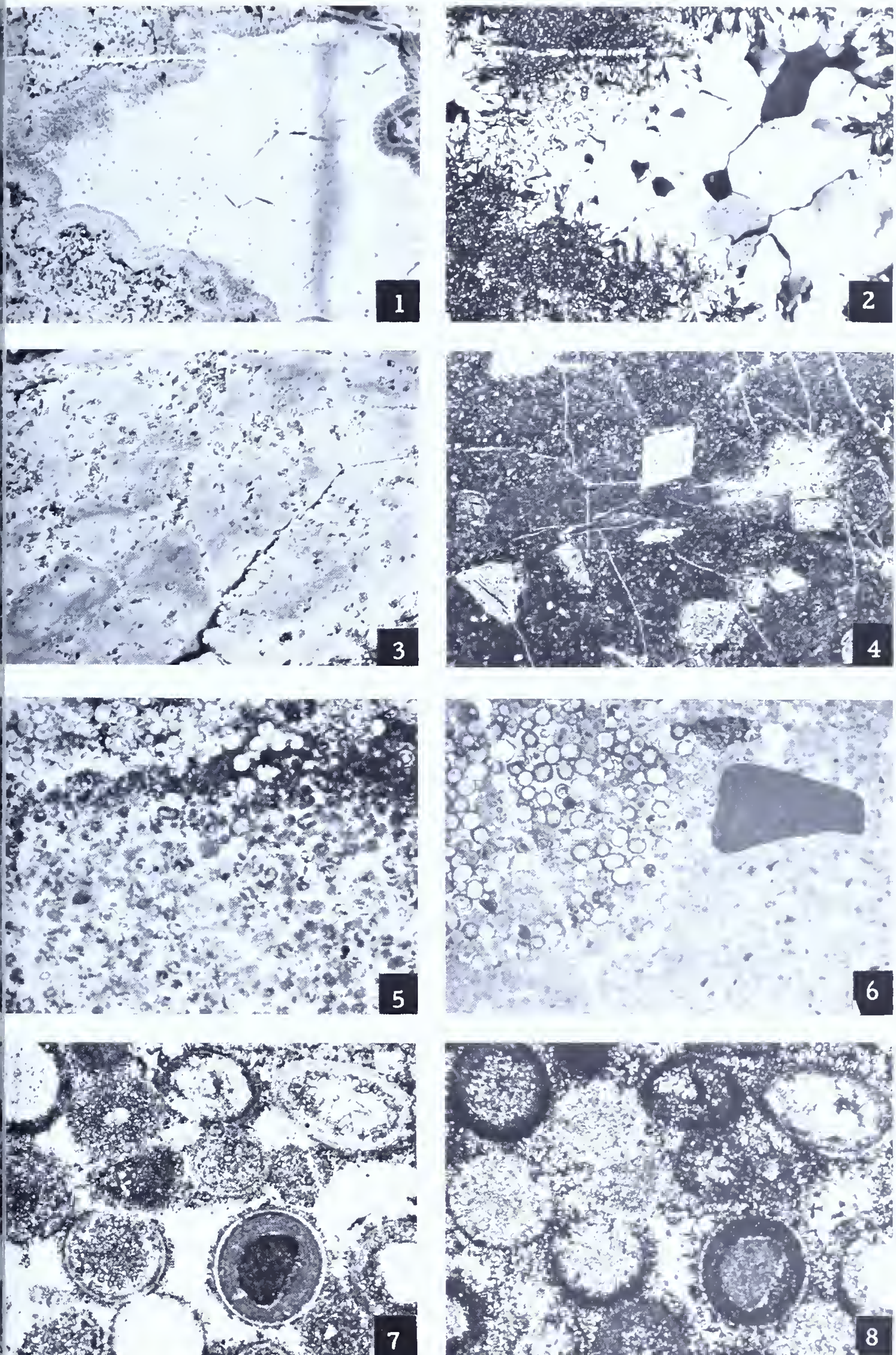

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PLATE 5.—VARIETIES OF SILICA FOUND IN DOLOMITE SAMPLES FROM THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate.

Figures 1-3. Massive chert.

Photomicrographs of silicified oolites in nodular oolitic chert. Clear rhombic-shaped crystals are dolomite; speckled and dark areas are microcrystalline quartz. Thin sections photographed under crossed nicols. Magnification X37.

Figure 1. Silicified oolites. The nature of the oolite nucleus is commonly destroyed during replacement by silica. However, the original sand-size quartz-grain nucleus is preserved in several oolites in this specimen. The siliceous oolite with the quartz-grain nucleus is partly replaced by a large rhombic-shaped dolomite crystal. Apparently the dolomite came after the silica because the structure of the chalcedonic quartz layer that forms the outer margin of the oolite is preserved in the dolomite rhomb. Mount Etna section, 215 feet above base of Nittany Dolomite.

Figure 2. Oolites are completely replaced by microcrystalline quartz but their outer margins, in turn, are penetrated by rhombic dolomite crystals. Poorly preserved concentric structures are visible in transmitted light. Mount Etna section, 215 feet above base of Nittany Dolomite.

Figure 3. Oolites are totally replaced by microcrystalline quartz. However, large rhombic-shaped dolomite crystals, in turn, replace the outer portion of silicified oolites. A large dolomite rhomb near the left margin of the figure replaces parts of three oolites and completely incorporates a fourth. Poorly preserved concentric structures are visible in transmitted light. Spruce Creek section, 185 feet above base on Nittany Dolomite.

Figures 4-6. Disseminated chert.

Shoenberger section, 379 feet below top of Nittany Dolomite.

Figure 4. Chert aggregates from the insoluble residue of a dolomite sample that was thoroughly lached with hydrochloric acid. The aggregates retain the shape of the original dolomite fragments. Chert aggregates are concentrations of microcrystalline quartz, and their strength is related to the amount of pore space, the degree of cementation, and the amount of interstitial clay material. Scale in mm. Magnification X2.7.

Figures 5 and 6. The debris of a crushed chert aggregate in water. Figure 5 photographed in transmitted light; Figure 6 shows the same field of view under crossed nicols. The aggregate appears to be composed of silt-size quartz grains that are cemented into a rigid mass by microcrystalline quartz. The larger particles extinguish as a unit. Their fuzzy outline is caused by thin coatings of microcrystalline quartz and clay. The larger silt-size grains may be either detrital or authigenic, but the cementing silica is probably authigenic. Magnification X56.

Figures 7 and 8. Frosted and pitted detrital sand-size quartz grains from the insoluble residue of a dolomite sample. Scale in mm. Shoenberger section, 71 feet below top of Nittany Dolomite.

Figure 9. Singly terminated authigenic quartz crystals from the insoluble residue of a dolomite sample. The nonterminated end is commonly a fracture surface. These crystals probably grew in small solution cavities in the host dolomite. Magnification X9.2. Shoenberger section, 177 feet below top of Nittany Dolomite.

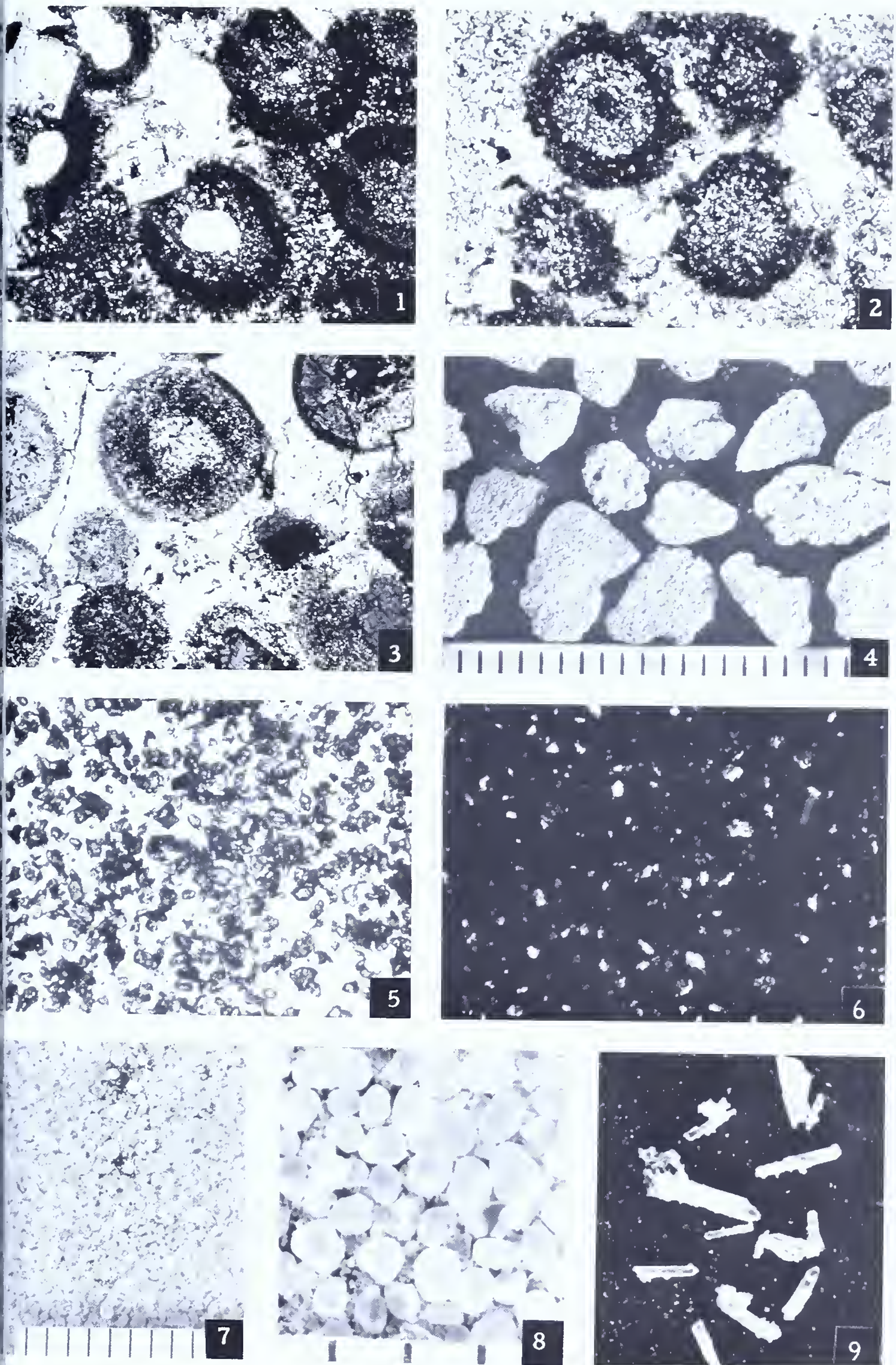
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PLATE 6.—PHOTOMICROGRAPHS OF GRANULAR CARBONATE COMPONENTS IN DOLOMITES OF THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X4.4 for all figures.

Figure 1. Oolites in a medium-coarsely crystalline, mottled and streaked dolomite. The oolites are replaced by crystals of dolomite averaging about 0.12 mm in diameter and occur within lighter colored areas composed of crystals of dolomite averaging about 0.07 mm in diameter. Dolomitization has destroyed the concentric structure of the oolites, and the outlines of many are suboval, possibly caused by compaction due to the weight of overlying sediments. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 2. Pellets in a medium-crystalline dolomite. Small, dark-brown, subcircular, structureless particles comprise nearly the bulk of the sample. They average about 0.08 mm in diameter and are interpreted as being pellets. However, the manner in which they originally developed is unknown. Shoenberger section, 179 feet below top of Nittany Dolomite.

Figure 3. Oolites and rock fragments in a coarsely crystalline dolomite. Rock fragments are larger than the oolites and their long dimension tends to be oriented parallel to bedding. The concentric structure of the oolites was destroyed during dolomitization and the outlines of many are distorted. Mount Etna section, 818 feet above base of Nittany Dolomite.

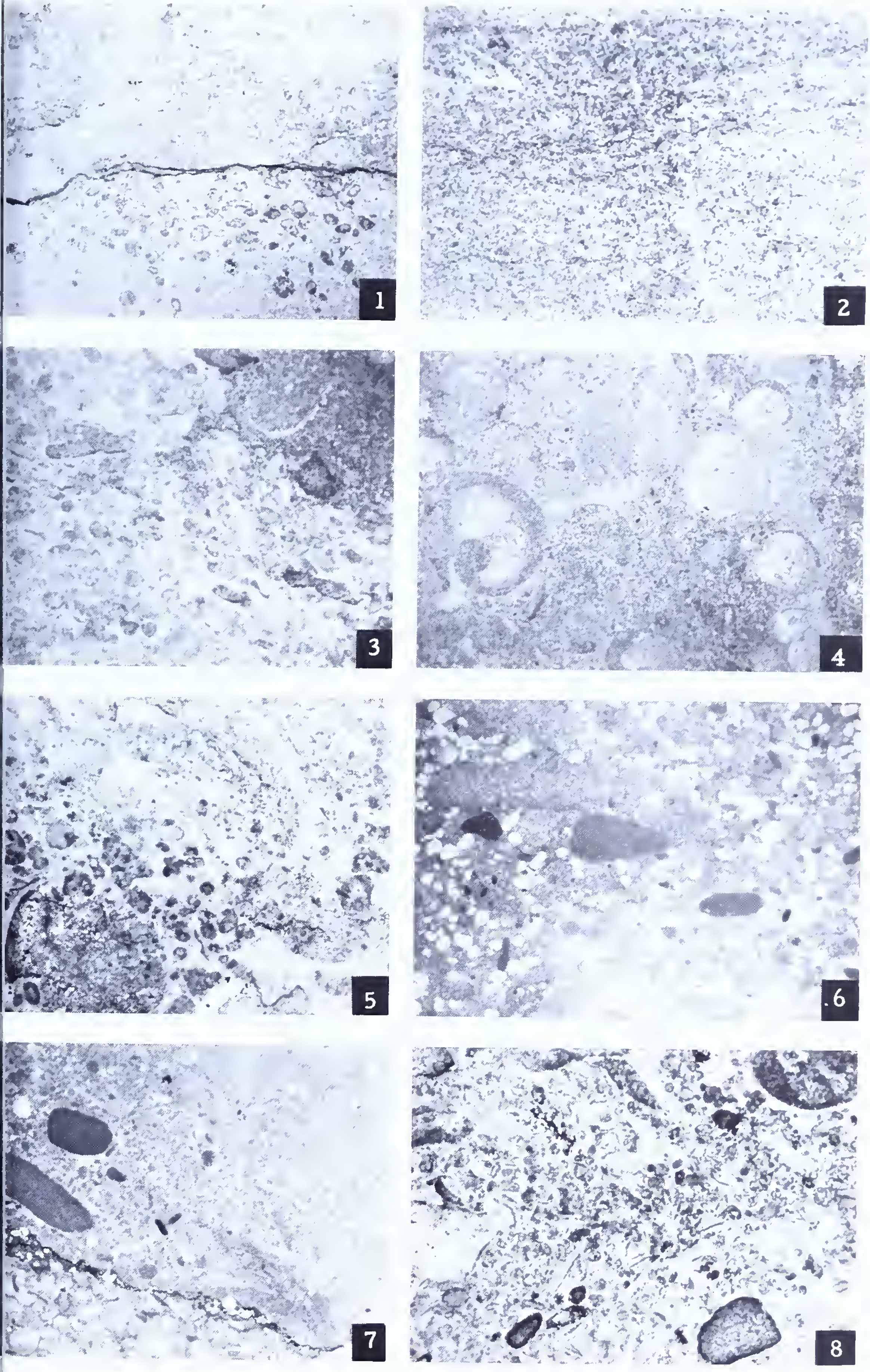
Figure 4. Fossils in a medium-crystalline dolomite. Small, low-spired gastropods occur throughout the sample. The original shell material, and the fine-grained sediment trapped inside many of the shells, is replaced by dolomite. Internal chambers in several shells are filled with sparry dolomite crystals. The shells show little evidence of abrasion. Mount Etna section, 975 feet above base of Nittany Dolomite.

Figure 5. Fossils, oolites and rock fragments, many of which contain oolites and fossils, in a coarsely crystalline dolomite. In many oolites the concentric structure is partly preserved but in most it has been destroyed. The shape of the fragment containing oolites and fossils is in part controlled by these items. Bivalve shells occurring in a fragment that also contains oolites are visible in the lower left corner of the figure. The specimen is very poorly sorted. West Bellefonte section, 530 feet above base of Nittany Dolomite.

Figure 6. Carbonate rock fragments in a medium-crystalline dolomite. The fragments are composed of more finely crystalline dolomite than the surrounding carbonate material. This sample also contains abundant sand-size quartz grains that are distributed throughout. Williamsburg section, 254 feet above base of Nittany Dolomite.

Figure 7. Rock fragments and oolites in a medium-crystalline dolomite. The oolites are very poorly preserved and it is nearly impossible to recognize them in the hand specimen. Sand-size quartz grains are distributed throughout the specimen. Williamsburg section, 153 feet above base of Nittany Dolomite.

Figure 8. Rock fragments, oolites, and various types of fossils in a medium-coarsely crystalline dolomite. The specimen contains an unusually complex assemblage of grain types. Pelmatozoan plates are the most abundant fossil type in the sample, and several low-spired gastropods and bivalve shells also occur. Many rock fragments contain no recognizable grains, whereas others incorporate



Scale 1 cm

PLATE 6.—Continued

fossils and oolites. The sample is very poorly sorted and may represent a lag deposit from which the finer grained material was winnowed away. Dark borders around many of the rock fragments are caused by concentrations of yellowish-brown material, probably altered pyrite. West Bellefonte section, 497 feet above base of Nittany Dolomite.

PLATE 7.—PHOTOMICROGRAPHS OF GRANULAR CARBONATE COMPONENTS IN DOLOMITES OF THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X25 for all figures.

Figure 1. Oolites in dark-grey, coarsely crystalline dolomite. The concentric structure and nature of the nucleus are destroyed but the oolite outlines are moderately well preserved. Xenomorphic to hypidiomorphic dolomite crystals averaging about 0.15 mm in diameter form an interlocking network of dolomite crystals that have replaced both the oolites and the surrounding interstitial carbonate material. Mount Etna section, 818 feet above base of Nittany Dolomite.

Figure 2. Oolites and pellets in a dark-grey, coarsely crystalline, mottled, granular dolomite. The oolites in the left half of the figure are moderately well preserved, and are surrounded by idiomorphic dolomite crystals that average about 0.055 mm in diameter. Smaller subcircular particles, possibly pellets, occur in the right side of the figure within idiomorphic to hypidiomorphic dolomite crystals averaging about 0.12 mm in diameter. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 3. Pellets in a medium-crystalline, pelletic dolomite. The small dark-brown, subcircular, structureless particles that occur throughout the specimen and average about 0.08 mm in diameter are referred to as pellets. They are incorporated into xenomorphic dolomite crystals averaging about 0.16 mm in diameter. Pellets are characteristically included within a single dolomite crystal, but in several instances the margin between two crystals passes through the particle. Relatively few dolomite crystals contain more than one pellet. Shoenberger section, 179 feet below top of Nittany Dolomite.

Figure 4. Rock fragments in a coarsely crystalline, mottled, oolitic dolomite. The large central fragment contains poorly preserved oolites that appear to control the shape of the fragment. The rounded corners coincide with oolites, and at only one place does the fragment margin appear to cut across an oolite. Apparently the oolites are more resistant to abrasion than the carbonate material that binds them together into a fragment. The dolomite crystals replacing the fragment and surrounding carbonate material are hypidiomorphic and average about 0.20 mm in diameter. West Bellefonte section, 530 feet above base of Nittany Dolomite.

Figure 5. Pelmatozoan plates (near lower margin and along the right margin of the figure midway between top and bottom), rock fragments, and oolites in a medium-crystalline granular dolomite. The pelmatozoan plates are identified on the basis of shape and their occurrence as unit crystals. However, the outer margins of many plates are replaced by smaller idiomorphic dolomite crystals that extend across the margin into the surrounding interstitial material. The large rock fragment contains opaque, yellowish-brown material, possibly altered pyrite, that is especially concentrated at its margin. Very poorly preserved oolites occur

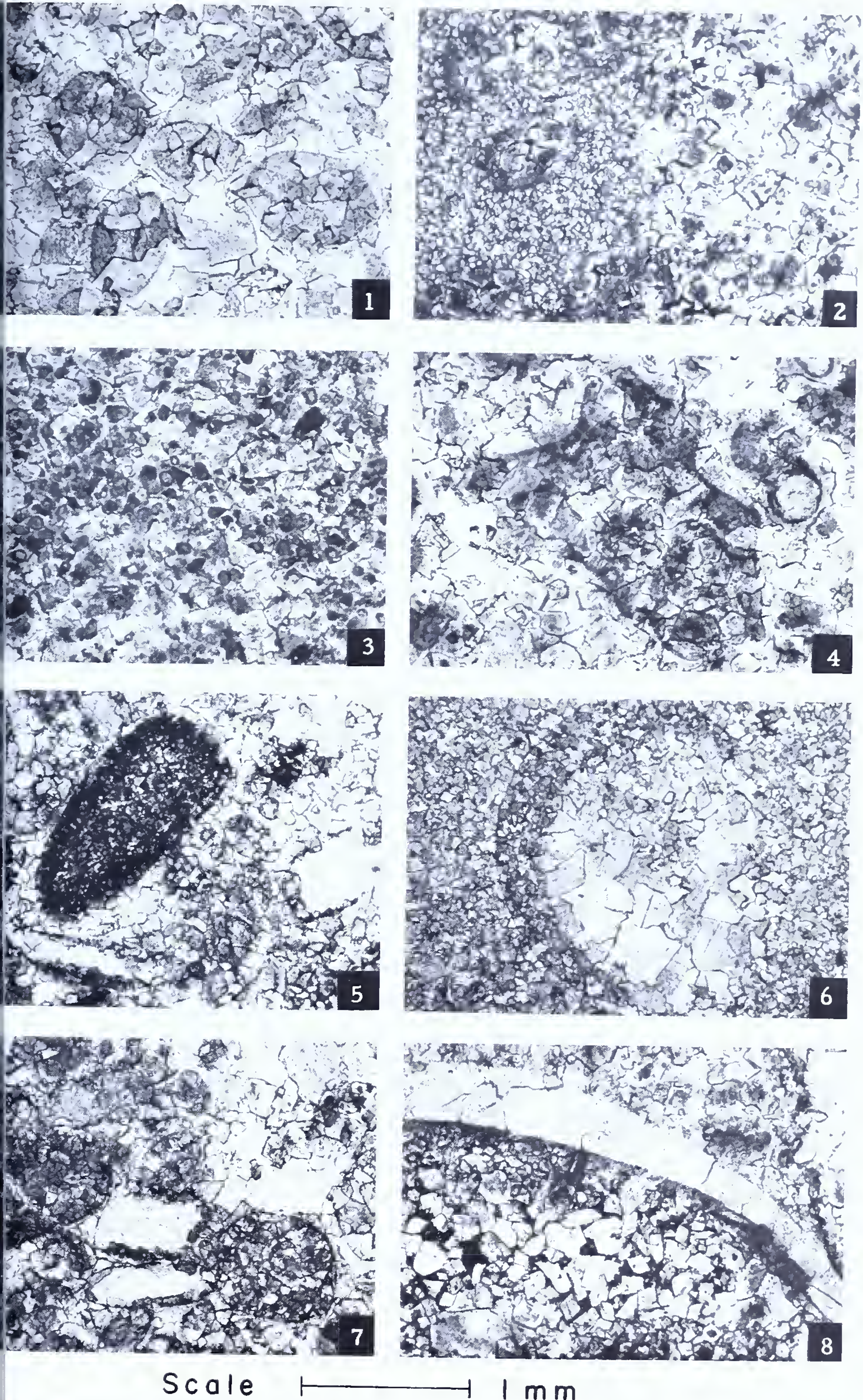

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PLATE 7.—Continued

in the area between the two pelmatozoan plates and the rock fragment. Dolomite crystals are predominantly hypidiomorphic and average about 0.10 mm in diameter. West Bellefonte section, 497 feet above base of Nittany Dolomite.

Figure 6. Gastropod shell in a medium-crystalline, fossiliferous dolomite. The dolomitized shell occurs directly to the left of the line which outlines the shape of the fossil. To the right of this line the dolomite is more finely crystalline and contains some silt-size quartz grains. This material may have originally been lime mud or fine-grained sediment that was trapped inside the shell. Sparry dolomite crystals fill the internal chambei of the shell. Crystals in the dolomitized shell average about 0.08 mm in diameter and are slightly larger than the surrounding interstitial carbonate material. Mount Etna section, 975 feet above base of Nittany Dolomite.

Figure 7. Pelmatozoan plates and rock fragments in a medium-crystalline, granular dolomite. The dolomite crystals are predominantly xenomorphic and average about 0.12 mm in diameter. West Bellefonte section, 497 feet above base of Nittany Dolomite.

Figure 8. Bivalve shell, probably a brachiopod, in a coarsely crystalline, mottled, oolitic, fossiliferous dolomite. Many of the dolomite erystals replacing the shell extend upward into the overlying interstitial material. Idiomorphic dolomite crystals and interstitial chert occur beneath the shell. West Bellefonte section, 530 feet above base of Nittany Dolomite.

PLATE 8.—ACID ETCHED SECTIONS SHOWING SEDIMENTARY STRUCTURES DEVELOPED IN DOLOMITES OF THE NITTANY FORMATION

Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate. Magnification X3.4 for all figures.

Figure 1. Structureless dolomite. The sample is composed of finely crystalline dolomite; insoluble components are distributed uniformly throughout the sample. Spruce Creek section, 137 feet above base of Nittany Dolomite.

Figure 2. Laminated dolomite. The laminae that etch in relief contain abundant amounts of silt-size quartz grains and minor amounts of sand-size grains. Spring Creek section, 45 feet above base of Nittany Dolomite.

Figure 3. Mottled dolomite. Irregular-shaped interconnecting patches of medium-crystalline dolomite that occur within coarsely crystalline dolomite produce a mottled appearance in the specimen. Interstitial chert between coarsely crystalline dolomite crystals causes the coarsely crystalline areas to etch in relief. Mount Etna section, 963 feet above base of Nittany Dolomite.

Figure 4. Mottled dolomite. Dark mottled areas in the sample are composed of a mixture of argillaceous-siliceous material and silt-size quartz grains. Shoenberger section, 402 feet below top of Nittany Dolomite.

Figure 5. Streaked dolomite. Streaks are composed of a mixture of argillaceous-siliceous material. Streaks in dolomite samples of the Nittany Formation characteristically occur in an anastomosing manner. Mount Etna section, 525 feet above base of Nittany Dolomite.

Figure 6. Streaked dolomite. Streaks are composed of siliceous material. In general, lighter colored streaks contain little argillaceous material. The streaks coalesce

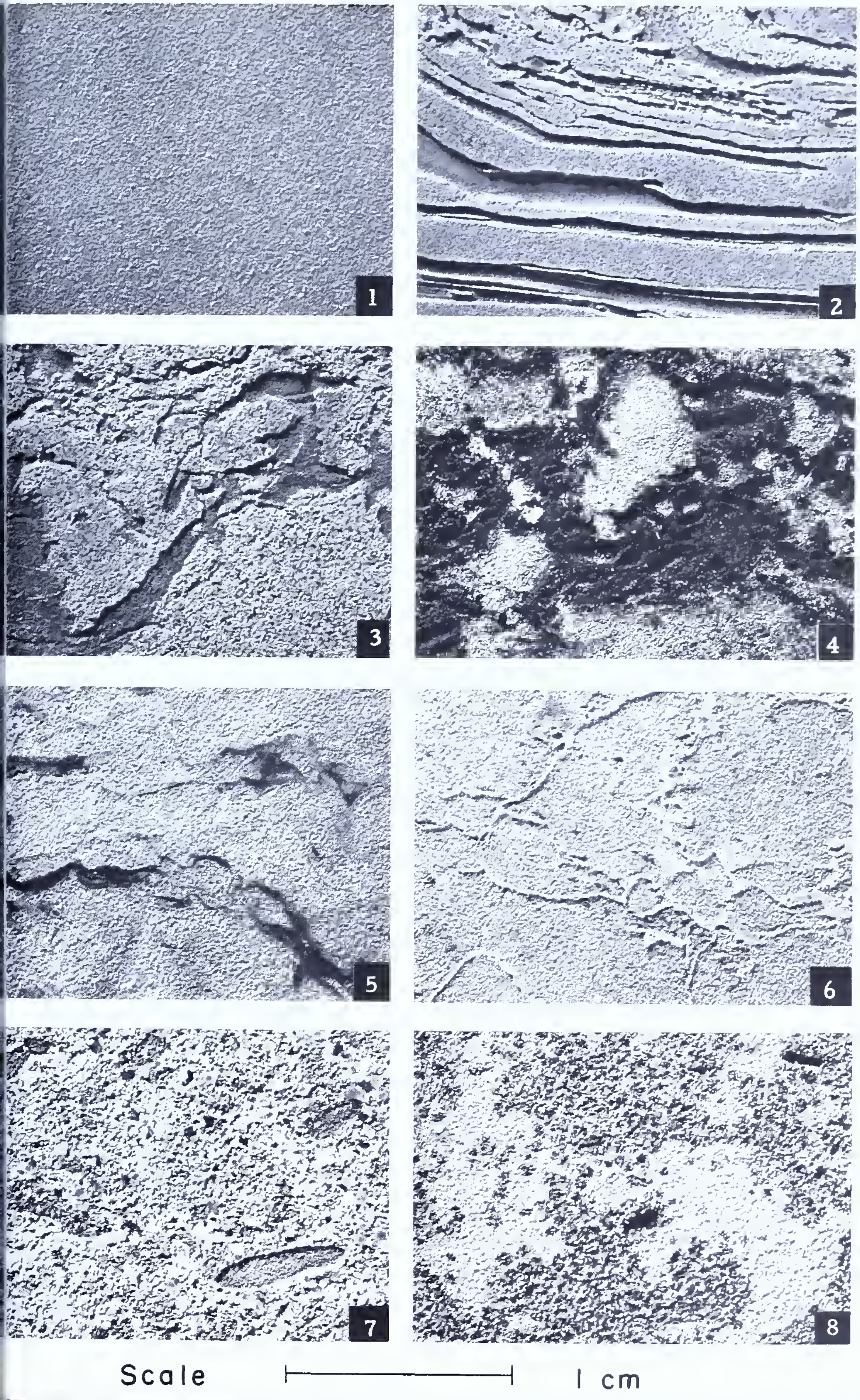
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PLATE 8.—Continued

in places and the specimen assumes a slightly mottled appearance. Spruce Creek section, 120 feet above base of Nittany Dolomite.

Figure 7. Granular dolomite. Carbonate rock fragments that differ in size but having rounded outlines occur throughout the sample. Sand-size quartz grains also are distributed throughout the specimen. The occurrence of carbonate rock fragments, and not quartz grains, is the criterion used to classify the rock as granular. Waterside section, 807 feet above base of Nittany Dolomite.

Figure 8. Granular dolomite. Poorly preserved dark-grey oolites are most easily observed in the light grey regions that also give the specimen a mottled appearance. Oolites were observed only in the more coarsely crystalline dolomites. West Bellefonte section, 460 feet above base of Nittany Dolomite.

PLATE 9.—PHOTOMICROGRAPHS OF SEDIMENTARY STRUCTURES DEVELOPED IN DOLOMITES OF THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X4.4 for all figures.

Figure 1. Finely crystalline, structureless dolomite. The sample consists of an interlocking network of xenomorphic dolomite crystals averaging about 0.025 mm in diameter. Small black particles are altered grains of pyrite. This sample is shown at higher magnification in Plate 10, Figure 1. Spruce Creek section, 30 feet above base of Nittany Dolomite.

Figure 2. Coarsely crystalline, structureless dolomite. The sample contains a very small percentage of silt-size quartz grains and small patches of interstitial chert. Both items are distributed rather uniformly throughout the specimen. The fracture was produced during the preparation of the thin section. West Bellefonte section, 389 feet above base of Nittany Dolomite.

Figure 3. Finely crystalline, laminated dolomite. The light-colored laminae contain a large percentage of silt-size quartz grains. Slumpage, or possibly burrowing animals, have broken the upper laminae into fragments that have been redeposited in a somewhat chaotic manner. The sample is shown at a higher magnification in Plate 1, Figure 2. Spring Creek section, 45 feet above base of Nittany Dolomite.

Figure 4. Medium-crystalline, laminated dolomite. The laminae are layers in which interstitial chert is concentrated. Dolomite crystals in the specimen average about 0.1 mm in diameter. Lutzville section, 675 feet above base of Nittany Dolomite.

Figure 5. Finely crystalline, streaked dolomite. The streaks occur as an anastomosing network of very thin layers composed of argillaceous-siliceous material. Silt-size quartz grains occur within these layers. The sample is shown at a higher magnification in Plate 10, Figure 8, Shoenberger section, 402 feet below top of Nittany Dolomite.

Figure 6. Medium-crystalline, streaked dolomite. The streaks are composed of a mixture of silt-size quartz grains and argillaceous-siliceous material. In addition, streaks composed of clear and coarser dolomite crystals occur throughout the sample. The specimen is shown at a higher magnification in Plate 3, Figures 3 and 4. Mount Etna section, 525 feet above base of Nittany Dolomite.

Figure 7. Medium-crystalline, mottled dolomite. The mottled areas consist of

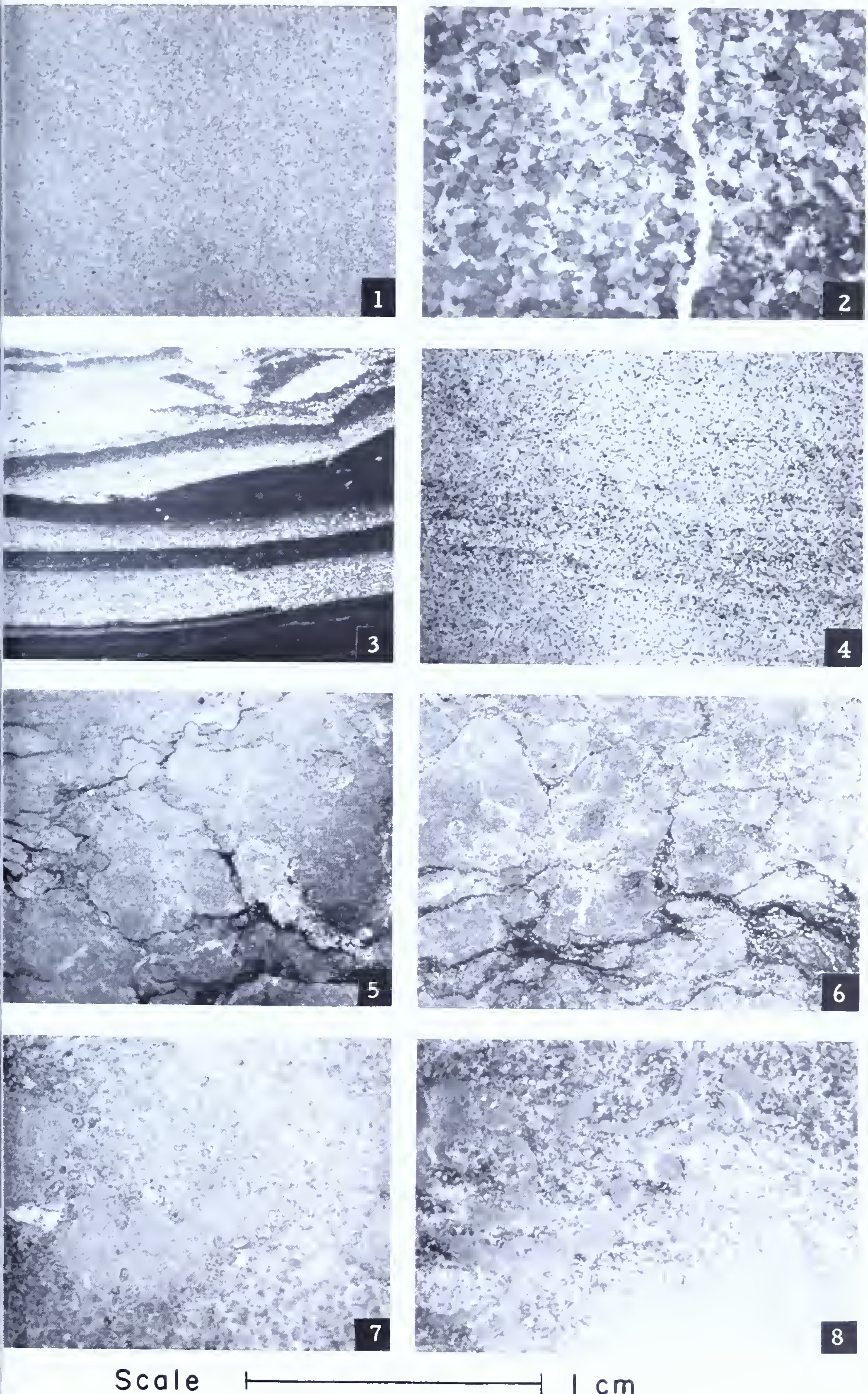
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PLATE 9.—Continued

medium-crystalline dolomite and contain some oolites that have been replaced by slightly larger crystals of dolomite. However, the bulk of the sample is made up of poorly preserved dolomitized oolites. The sample is shown at a higher magnification in Plate 1, Figure 3. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 8. Medium-coarsely crystalline, mottled dolomite. The mottling is produced by irregular-shaped interconnected patches of medium-crystalline dolomite that occur within a sample that is made up of dolomite crystals ranging in size from medium to coarsely crystalline. Mount Etna section, 963 feet above base of Nittany Dolomite.

PLATE 10.—PHOTOMICROGRAPHS OF SEDIMENTARY STRUCTURES DEVELOPED IN DOLOMITES OF THE NITTANY FORMATION

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate. Magnification X25 for all figures.

Figure 1. Finely crystalline structureless dolomite. The sample consists of an interlocking network of xenomorphic and less commonly hypidiomorphic dolomite crystals. Silt-size quartz grains and opaque grains, possibly altered pyrite, occur rarely throughout the sample. A very small amount of clay is distributed throughout the specimen; it occurs between the dolomite crystals as an interstitial impurity. Dolomite crystals average about 0.025 mm in diameter. Spruce Creek section, 30 feet above base of Nittany Dolomite.

Figure 2. Coarsely crystalline structureless dolomite. The sample is composed of an interlocking network of hypidiomorphic and idiomorphic dolomite crystals. Yellowish-brown stained amorphous chert occurs abundantly throughout the specimen as interstitial material. The twinned dolomite crystal slightly to the right of center is 0.58 mm long along the twinning plane. Williamsburg section, 190 feet above base of Nittany Dolomite.

Figures 3 and 4. Finely crystalline, laminated dolomite. Figure 4 shows the same field of view as Figure 3 but is photographed under crossed nicols. Laminations in the sample are alternating layers in which the concentration of silt-size quartz grains varies from abundant to rare. In addition, dolomite crystals in the quartz-rich laminae are coarser than crystals in the quartz-free laminae. The dolomite crystals in the quartzitic laminae average about 0.050 mm in diameter and vary in shape from hypidiomorphic to idiomorphic, whereas dolomite crystals in the non-quartzitic layers are xenomorphic and average about 0.020 mm in diameter. Spring Creek section, 45 feet above base of Nittany Dolomite.

Figure 5. Finely crystalline, mottled dolomite. The mottled area is composed of a mixture of silt-size quartz grains, yellowish-brown stained argillaceous and siliceous material and xenomorphic dolomite crystals. Mottling in the specimen is produced by concentrations of various types of insoluble material. The silt-size quartz grains in the sample are not rounded but are angular and appear as clear grains in the figure. Their average diameter is about 0.050 mm. Mount Etna section, 525 feet above base of Nittany Dolomite.

Figure 6. Coarsely crystalline, mottled dolomite. Irregular-shaped interconnected patches of xenomorphic dolomite crystals averaging about 0.025 mm in diameter occur within an interlocking network of xenomorphic dolomite crystals aver-

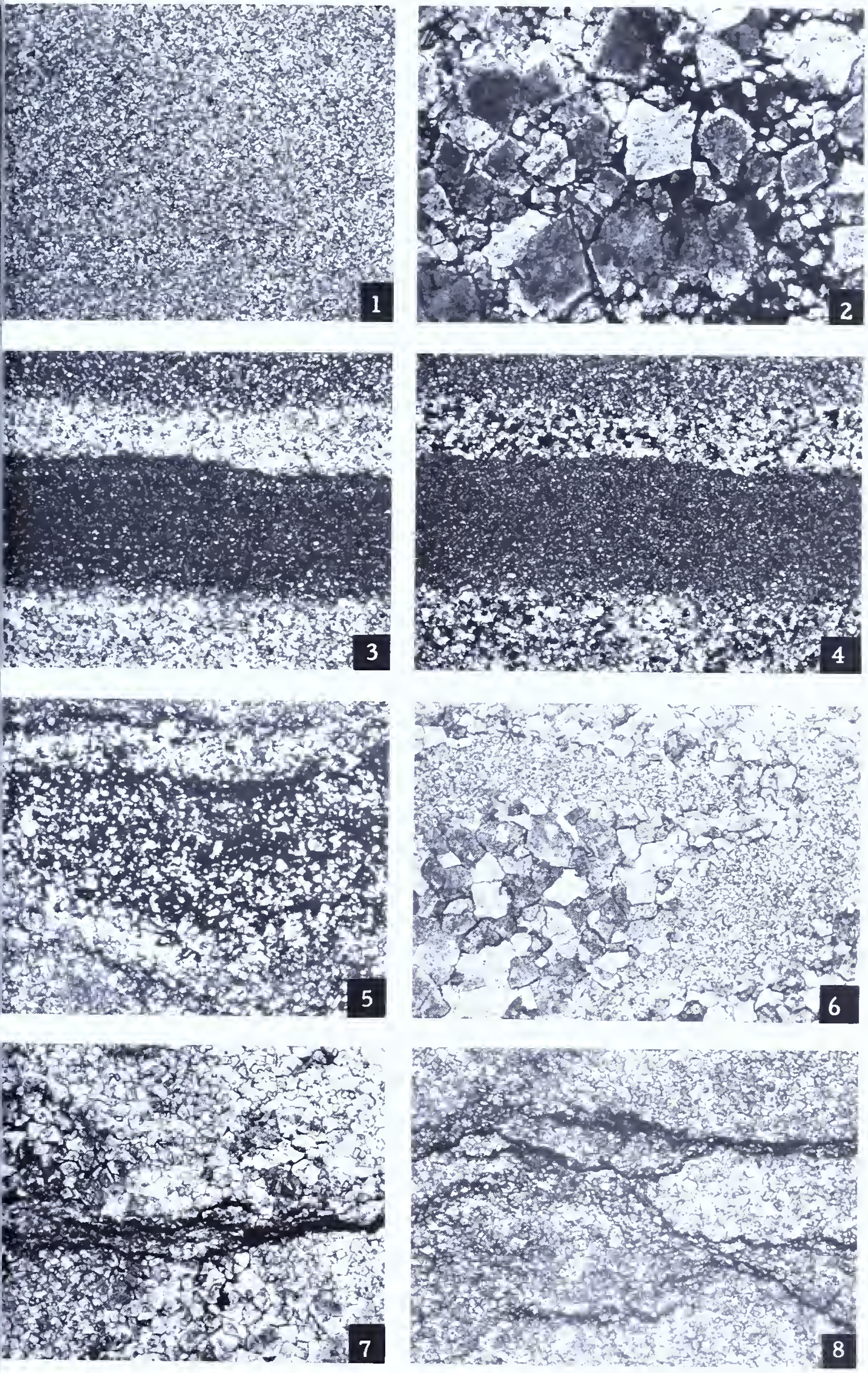
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PLATE 10.—Continued

aging about 0.25 mm in diameter. The dark margins between the coarse crystals are caused by opaque interstitial chert. Silt-size quartz grains occur rarely throughout the sample. Mottling in this dolomite sample results from differences in crystal sizc. Mount Etna section, 963 feet above base of Nittany Dolomite.

Figure 7. Streaks in a medium-coarsely crystalline, mottled, oolitic dolomite. The streaks are concentrations of opaque, yellowish-brown argillaceous-siliceous material intermixed with some silt-size quartz grains. Streaks in dolomite samples of the Nittany Formation characteristically display an anastomosing pattern. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 8. Finely crystalline, strcaked dolomite. Dark-brown, argillaceous-siliceous material is concentrated into very thin irregular layers that join with other layers to form an anastomosing network of streaks throughout the rock. The dolomite crystals in this sample average about 0.040 mm in diameter. Shoenberger section, 402 feet below top of Nittany Dolomite.

PLATE 11.—ACID ETCHED SECTIONS OF REPRESENTATIVE LITHOTYPES AND SUBLITHOTYPES OF THE NITTANY DOLOMITE

Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate. Magnification X1.8 for all figures.

Figure 1. Finely crystalline, structureless dolomite. The insoluble material is distributed uniformly throughout the sample. Spruce Creek section, 137 feet above base of Nittany Dolomite.

Figure 2. Medium-coarsely crystalline, structureless dolomite. The sample contains a relatively large percentage of interstitial chert that is distributed uniformly throughout the rock and is etched in relief in this figure. Spruce Creek section, 192 feet above base of Nittany Dolomite.

Figure 3. Finely crystalline, laminated dolomite. The laminae that are etched in relief contain a large percentage of silt-size quartz grains and some sand-size grains. Spring Creek section, 45 feet above base of Nittany Dolomite.

Figure 4. Finely crystalline, laminated dolomite. The laminae containing silt- and sand-size quartz grains etch in relief. West Bellefonte section, 540 feet above base of Nittany Dolomite.

Figure 5. Medium-crystalline, laminated dolomite. The laminae are concentrations of interstitial chert. Lutzville section, 675 feet above base of Nittany Dolomite.

Figure 6. Coarsely crystalline, laminated dolomite. The laminae are concentrations of interstitial chert. Mount Etna section, 1,071 feet above base of Nittany Dolomite.

Figure 7. Finely crystalline, mottled dolomite. The dark mottled areas that etch in relief are concentrations of argillaceous-siliceous material. Shoenberger section, 402 feet below top of Nittany Dolomite.

Figure 8. Medium-crystalline, mottled dolomite. The light- to medium-grey areas that etch in relief are concentrations of siliceous material. Mount Etna section, 738 feet above base of Nittany Dolomite.

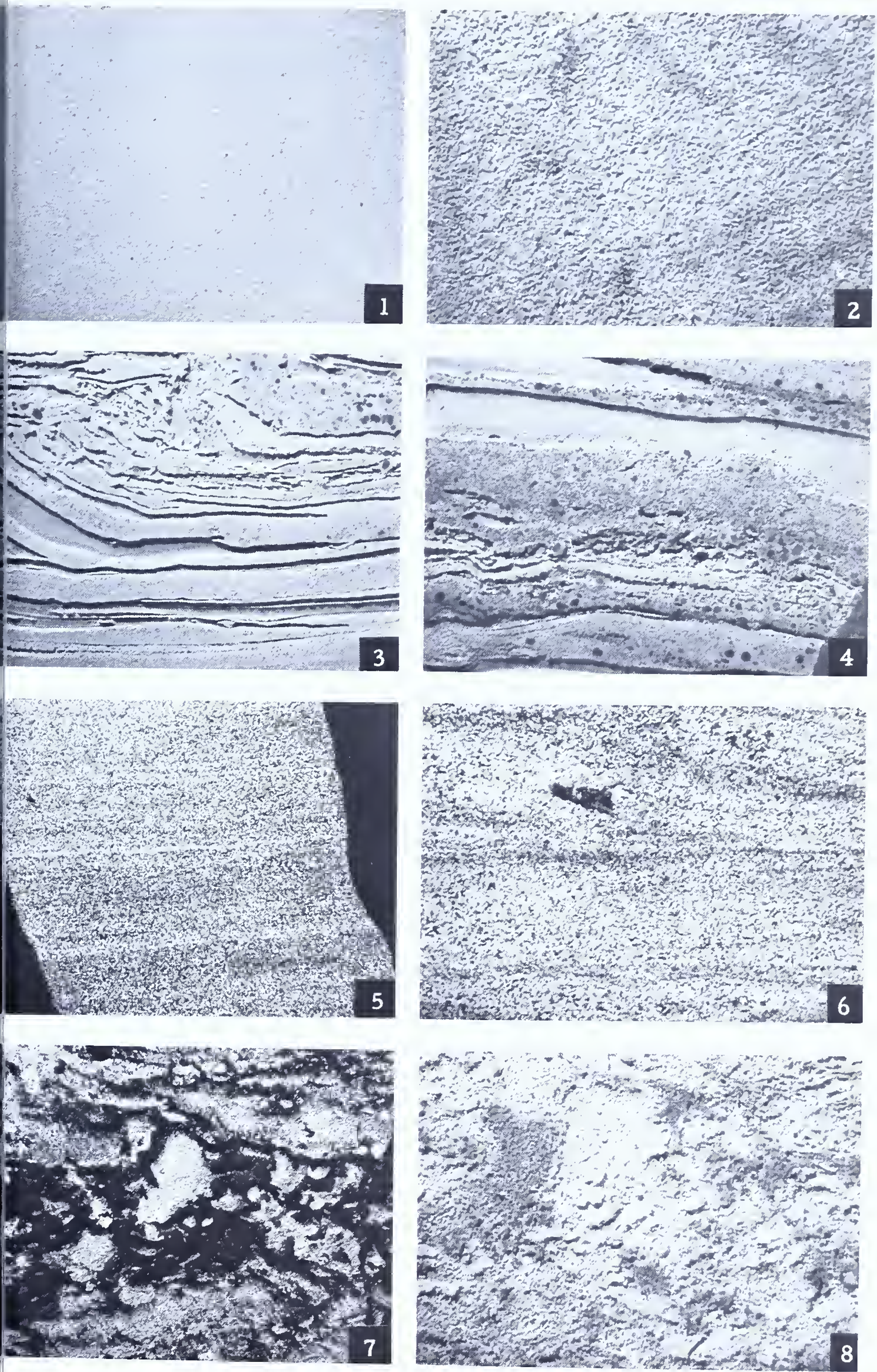

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PLATE 12.—ACID ETCHED SECTIONS OF REPRESENTATIVE LITHOTYPES AND SUBLITHOTYPES OF THE NITTANY DOLOMITE

Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate. Magnification X1.8 for all figures.

Figure 1. Medium-crystalline, mottled dolomite. The darker mottled areas are composed of finely crystalline dolomite; the lighter portion of the sample consists of coarsely crystalline dolomite. Mount Etna section, 963 feet above base of Nittany Dolomite.

Figure 2. Medium-coarsely crystalline, mottled dolomite. The lighter mottled areas are composed of medium-crystalline dolomite; the darker areas consist of coarsely crystalline dolomite that contains abundant sand-size quartz grains. Mount Etna section, 250 feet above base of Nittany Dolomite.

Figure 3. Finely-medium-crystalline, streaked and mottled dolomite. The streaks and mottling are composed of siliceous material that is etched in relief. Spruce Creek section, 120 feet above base of Nittany Dolomite.

Figure 4. Medium-crystalline, streaked dolomite. The streaks are composed of argillaceous-siliceous material that is etched in relief. Mount Etna section, 525 feet above base on Nittany Dolomitc.

Figure 5. Finely crystalline, granular dolomite. Laminae in this sample contain abundant silt-size quartz grains. In the lower part of the figure some of the laminae are broken into fragments that havc been incorporated into thc sediment in a chaotic manner. Spruce Creek section, 150 feet above base of Nittany Dolomite.

Figure 6. Coarsely crystalline, granular dolomite. The specimen contains carbonate rock fragments and some sand-size quartz grains. Waterside section, 807 feet above base of Nittany Dolomite.

Figure 7. Medium-coarsely crystalline, mottled, granular dolomite. The dark areas in the upper two-thirds of the sample are oolites replaced by coarsely crystallinc dolomite. West Bellefonte section, 460 feet above base of Nittany Dolomite.

Figure 8. Medium-coarsely crystalline, streaked, mottled, granular dolomite. The small circular dark areas are oolites; lighter colored streaks are composed of siliceous material. Mottling is due to medium-grey, medium-crystalline dolomite in dark-grey, coarsely crystalline dolomite. West Bellefonte section, 530 feet above base of Nittany Dolomite.

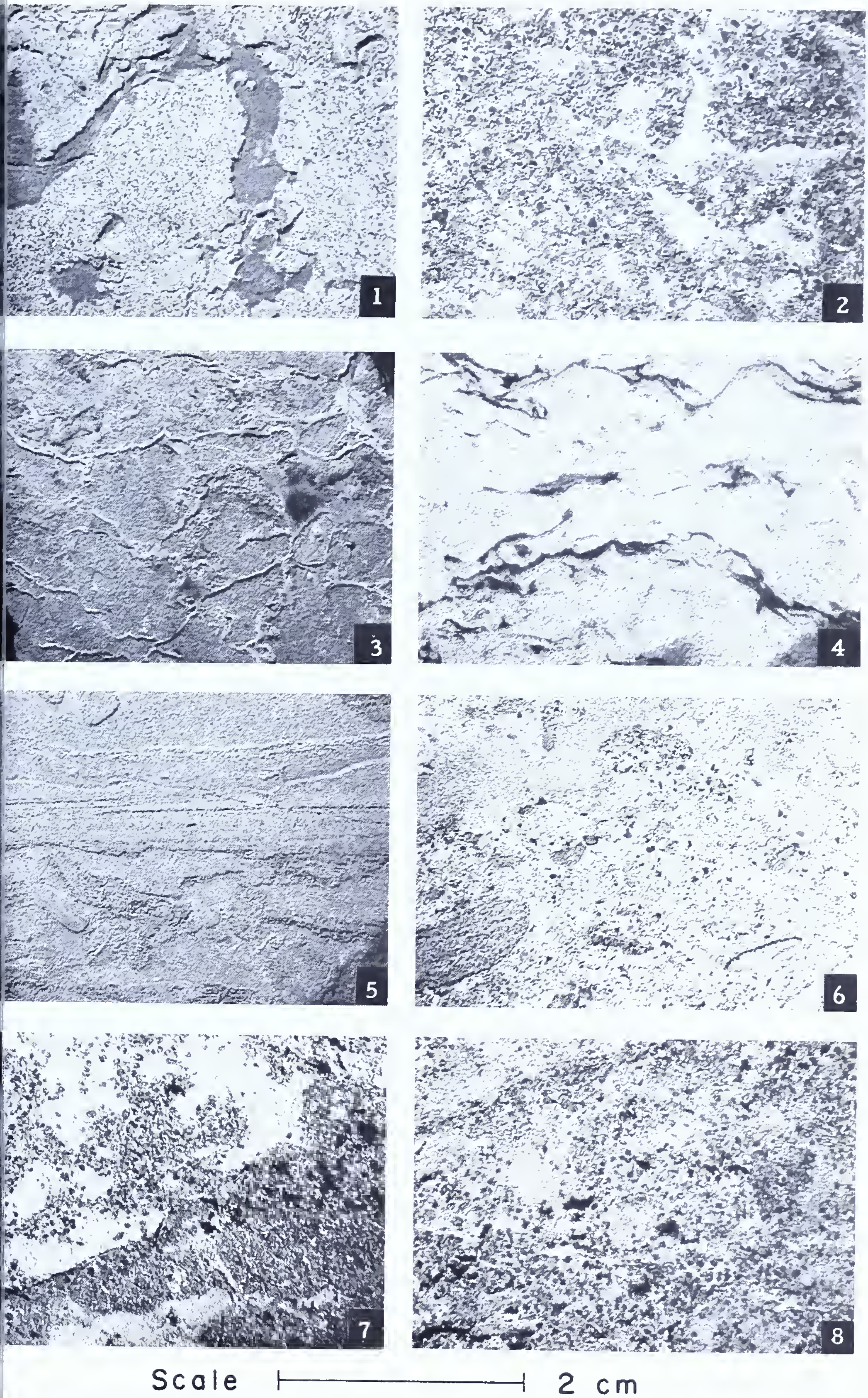
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PLATE 13.—DOLOMITE BEDS IN THE FORGE UNION MEMBER OF THE NITTANY DOLOMITE AT THE WEST BELLEFONTE SECTION

Figure 1. Cyclical sequences consisting of light-grey and dark-grey dolomite beds near the top of the Forge Union Member. The cycles consist of dark-grey, coarsely crystalline, mottled and oolitic dolomite (Figure 5) and light-grey, finely crystalline, laminated dolomite (Figure 4). A stone wall near the left margin of the figure is about 5.7 feet wide. The units shown in Figures 2 and 3 occur directly above and slightly to the left of the stone wall. The dolomite sequence shown in this figure extends from about 515 to 570 feet above base of Nittany Dolomite.

Figure 2. A cycle consisting of dark-grey, coarsely crystalline, mottled and oolitic dolomite overlain by light-grey, finely crystalline, laminated dolomite. The contact at the base of the dark coarsely crystalline dolomite bed is sharp, whereas its upper contact with light finely crystalline dolomite is transitional. A closeup of this transitional contact is shown in Figure 3. A 6-inch ruler is shown near the left margin of the figure. These beds occur between 556 and 567 feet above base of Nittany Dolomite.

Figure 3. Transitional contact between dark-grey, coarsely crystalline, mottled dolomite and light-grey, finely crystalline, laminated dolomite. About 565 feet above base of Nittany Dolomite.

Figure 4. Light-grey, finely crystalline, laminated dolomite. The darker laminae are concentrations of silt-size quartz grains and clay material. The larger laminae are continuous over the length of the exposure. They commonly are parallel to bedding, but some are slightly cross bedded and ripple marked. About 538 feet above base of Nittany Dolomite.

Figure 5. Dark-grey, coarsely crystalline, mottled and oolitic dolomite. The mottled areas are composed of light-grey, medium-crystalline dolomite. This unit and similar dolomite beds in the upper part of the Forge Union Member at Bellefonte commonly contain molds of *Lecanospira* sp. About 550 feet above base of Nittany Dolomite.

Figure 6. Laminae developed in light-grey, finely crystalline dolomite. The ruler near the lower margin is 6 inches high. About 540 feet above base of Nittany Dolomite.

Figure 7. A 4-inch bed of light-grey, finely crystalline dolomite that contains medium-grey, finely crystalline dolomite pebbles. Above this unit is a 2.5 inch bed of light-grey, finely crystalline, laminated dolomite, which in turn is overlain by an irregular, 1-inch-thick bed of dark-grey chert. About 340 feet above base of Nittany Dolomite.

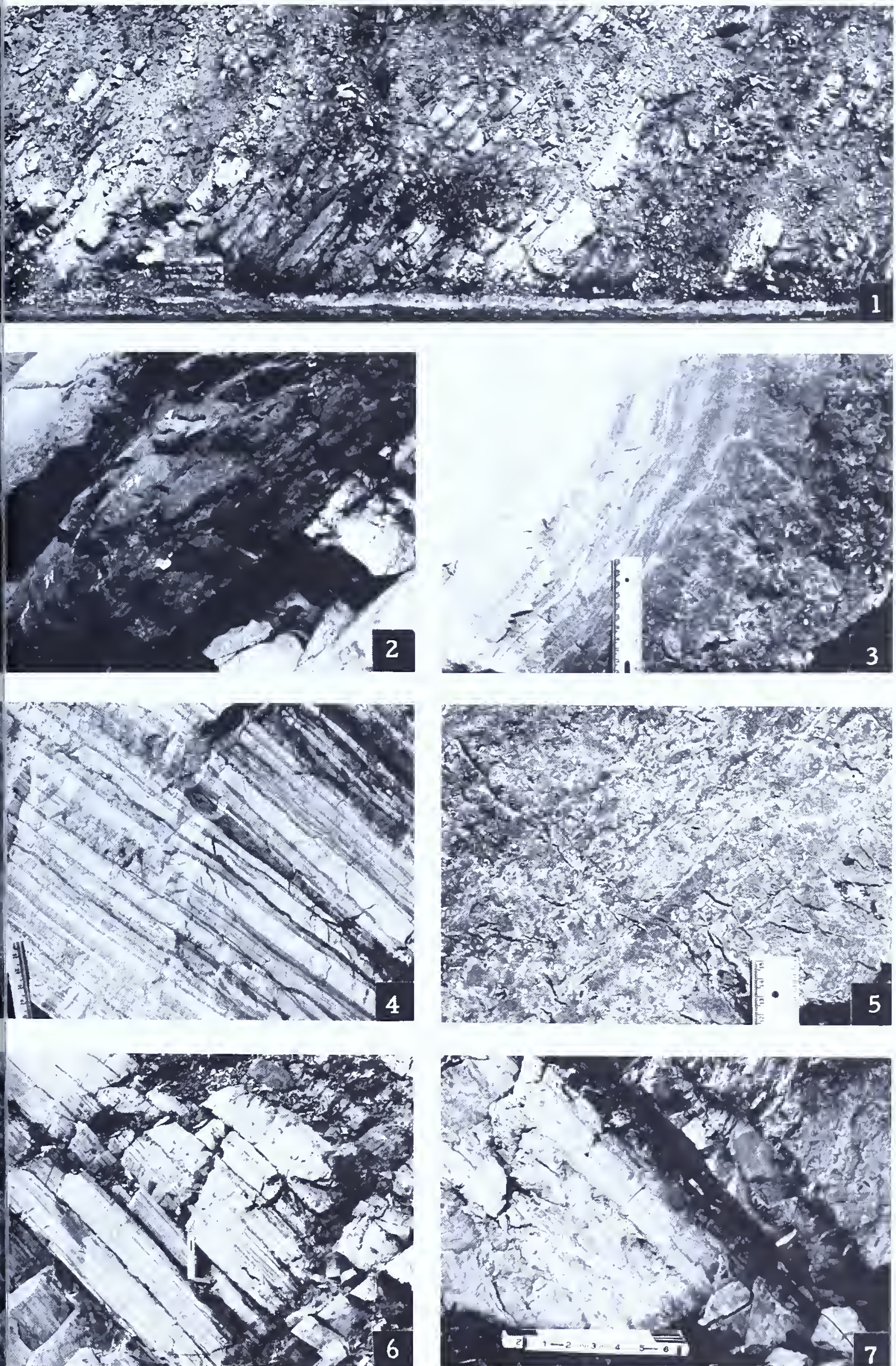
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PLATE 14.—DOLOMITE BEDS IN THE FORGE UNION MEMBER OF THE NITTANY DOLOMITE AT SECTIONS SOUTHWEST OF BELLEFONTE

Figure 1. A dolomite cycle near the base of the Nittany Dolomite at the Williamsburg section. Medium-light-grey, finely crystalline dolomite that weathers fissile is overlain by 1.5 feet of light-grey, finely crystalline, laminated and banded dolomite. The upper surface of this unit is irregular, and is overlain by a 6-inch to 1-foot bed of dark-grey, coarsely crystalline, structureless dolomite. A six-inch ruler is visible at the base of this bed near the left margin of the figure. The dark bed is overlain by light-grey, finely crystalline, laminated dolomite. Both the upper and lower contacts of the dark bed are sharp. About 35 to 45 feet above base of Nittany Dolomite.

Figure 2. Dolomite cycles in the upper part of the Williamsburg section. The cycles consist of dark-grey, medium-coarsely crystalline, mottled or structureless dolomite and light-grey, finely crystalline, laminated dolomite. The dark unit in the upper half of the figure is a 1-foot-thick bed of oolitic chert. All contacts are sharp but slightly irregular. A 3-foot ruler is located at the lower left margin of the figure. About 185 to 200 feet above base of Nittany Dolomite.

Figure 3. A dolomite cycle near the base of the Nittany Dolomite at the Spruce Creek section. A bed of medium-dark-grey, coarsely crystalline, structureless dolomite is overlain by light-grey, finely crystalline, faintly laminated dolomite. The contact between the two units is sharp, and thus contrasts with boundaries of similar beds in cycles in the Forge Union Member at Bellefonte. About 93 feet above base of Nittany Dolomite.

Figure 4. Cycles of light-grey, finely crystalline, laminated and structureless dolomite and dark-grey, medium-coarsely crystalline, mottled and streaked dolomite. All contacts between beds of these two dolomite types are sharp. Three light-grey and four dark-grey beds are shown in the figure. The lowest light-grey bed is marked by a painted number, 0 over 60. A 6-inch ruler is located at the base of this bed near the lower margin of the figure. Waterside section, about 175 to 200 feet above base of Nittany Dolomite.

Figure 5. Light-grey, irregular, nodular chert in light-grey, finely crystalline, faintly laminated dolomite. The upper surface of the unit appears to be ripple marked. Spruce Creek section, 187 feet above base of Nittany Dolomite.

Figure 6. Light-grey to tan, irregular, nodular chert in medium-light-grey, finely crystalline, laminated and banded dolomite. Many laminae are concentrations of silt- and sand-size quartz grains. A 6-inch ruler is visible near the right margin of the figure. Williamsburg section, 256 to 260 feet above base of Nittany Dolomite.

Figure 7. The bed in the lower half of the figure is light-grey, finely crystalline, laminated and banded dolomite. The laminae and bands are concentrations of sand-size quartz grains. This unit is overlain by medium-light-grey, medium-crystalline dolorudite that contains abundant sand-size quartz grains throughout. The light-grey dolomite pebbles also contain quartz sand and apparently were derived from the underlying dolomite bed. The scale in the figure is 6 inches high. Williamsburg section, about 253 feet above base of Nittany Dolomite.

Figure 8. Thick chert beds in coarsely crystalline, mottled and streaked dolomite. The lower chert bed is directly above the 3-foot ruler located near the lower left margin of the figure. Another chert bed that occurs at about the middle of the figure pinches out before reaching the left margin. Williamsburg section, about 270 feet above base of Nittany Dolomite.

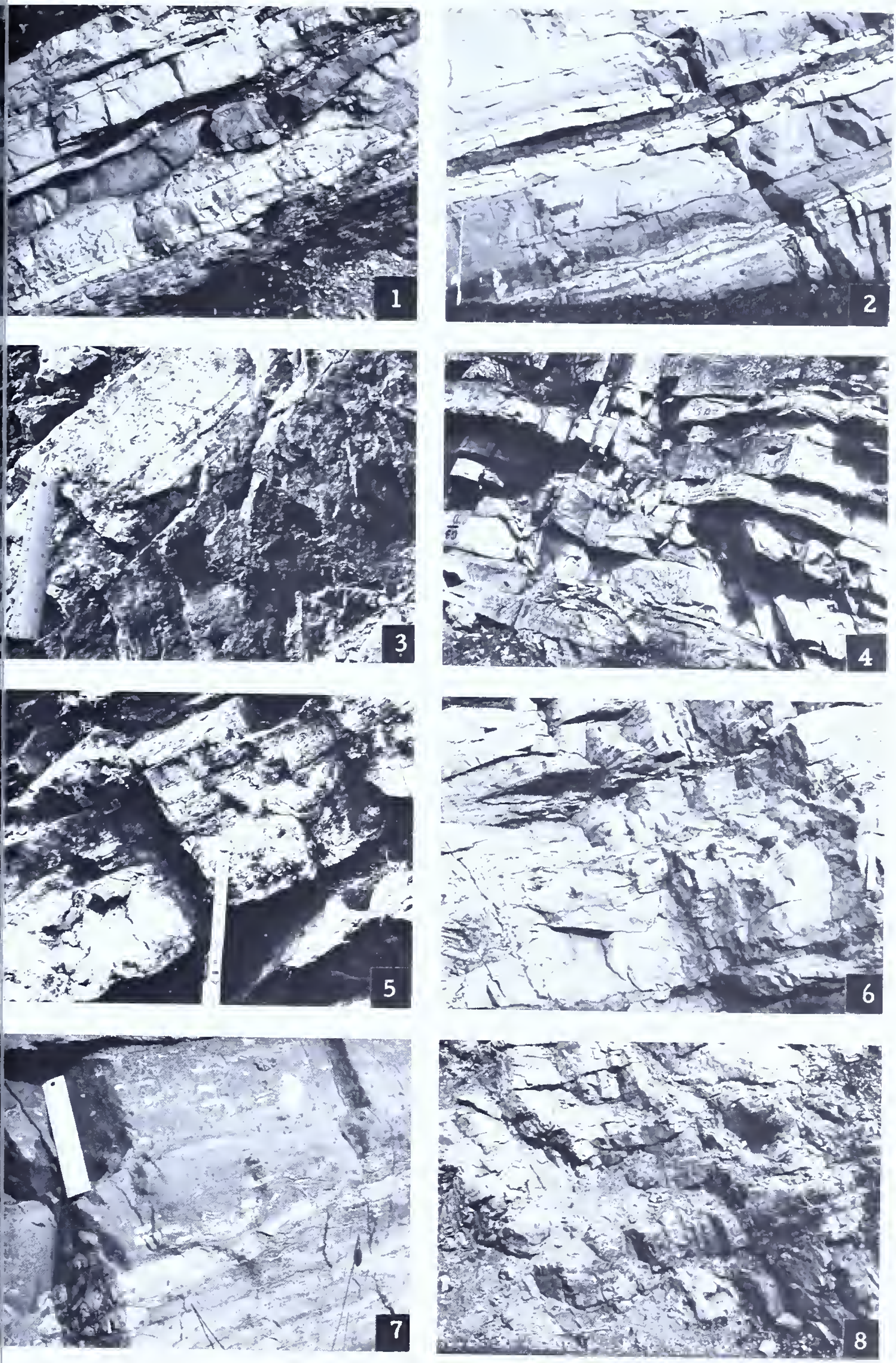
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PLATE 15.—BRACHIOPODS FROM THE NITTANY DOLOMITE

Figures 1 and 2. *Finkelnburgia* sp., X3.7, specimen, N-ME-175-1, Mount Etna section, about 1,060 feet above base of Nittany Dolomite. Exterior (1) and interior (2) views of silicified brachial valve.

Figures 3 and 4. *Diparelasma* sp., X4.5, specimen N-ME-153-1, Mount Etna section, about 963 feet above base of Nittany Dolomite. Exterior (3) and interior (4) views of silicified pedicle valve.

Figures 5 and 6. *Diparelasma* sp., X4.5, specimen N-ME-173-1b, Mount Etna section, about 1,055 feet above base of Nittany Dolomite. Exterior (5) and interior (6) views of silicified brachial valve.

Figures 7-18. *Tritoechia pennsylvanica,* Shoenberger section, about 130 feet below top of Nittany Dolomite. *7-10,* X3.3, specimen N-S-120-2. Exterior (7), interior (8), oblique interior (9) and side (10) views of silicified pedicle valve; *11-14,* X3.3, specimen N-S-120-1. Exterior (11), oblique interior (12), interior (13) and side (14) views of pedicle valve; *15,* X3.7, specimen N-S-120-20. Interior (15) view of silicified brachial valve; *16,* X3.7, specimen N-S-120-21. Interior (16) view of silicified brachial valve; *17,* X3.7, specimen N-S-120-11. Interior (17) view of silicified brachial valve; *18,* X3.7, specimen N-S-120-12. Exterior (18) view of silicified brachial valve.

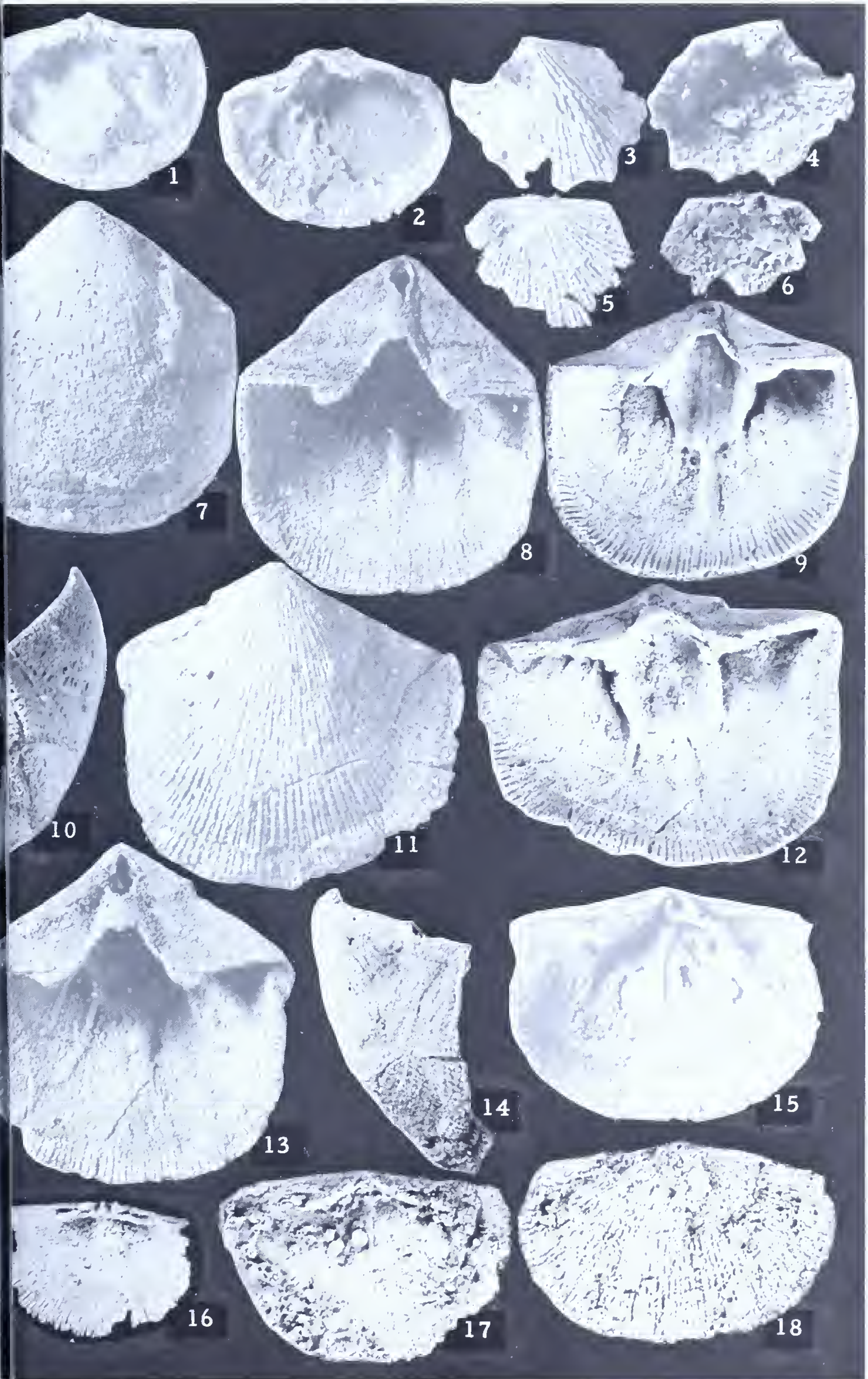
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PLATE 16.—BRACHIOPODS FROM NITTANY DOLOMITE

Figures 1-4. *Tritoechia pennsylvanica,* X3.5, specimen N-S-120-6, Shoenberger section, about 130 feet below top of Nittany Dolomite. Exterior (1), interior (2), side (3) and oblique interior (4) views of silicified brachial valve.

Figures 5-16. *Diaphelasma pennsylvanica,* X3.8, Baileyville section, about 380 feet above base of Nittany Dolomite. *5-8,* specimen N-Bv-43-2. Exterior (5), interior (6), oblique interior (7) and side (8) views of silicified pedicle valve; *9-12,* specimen N-Bv-43-1. Exterior (9), side (10), interior (11) and oblique interior (12) views of silicified pedicle valve; *13-16,* specimen N-Bv-43-3. Exterior (13), oblique interior (14), interior (15) and side (16) views of silicified brachial valve.

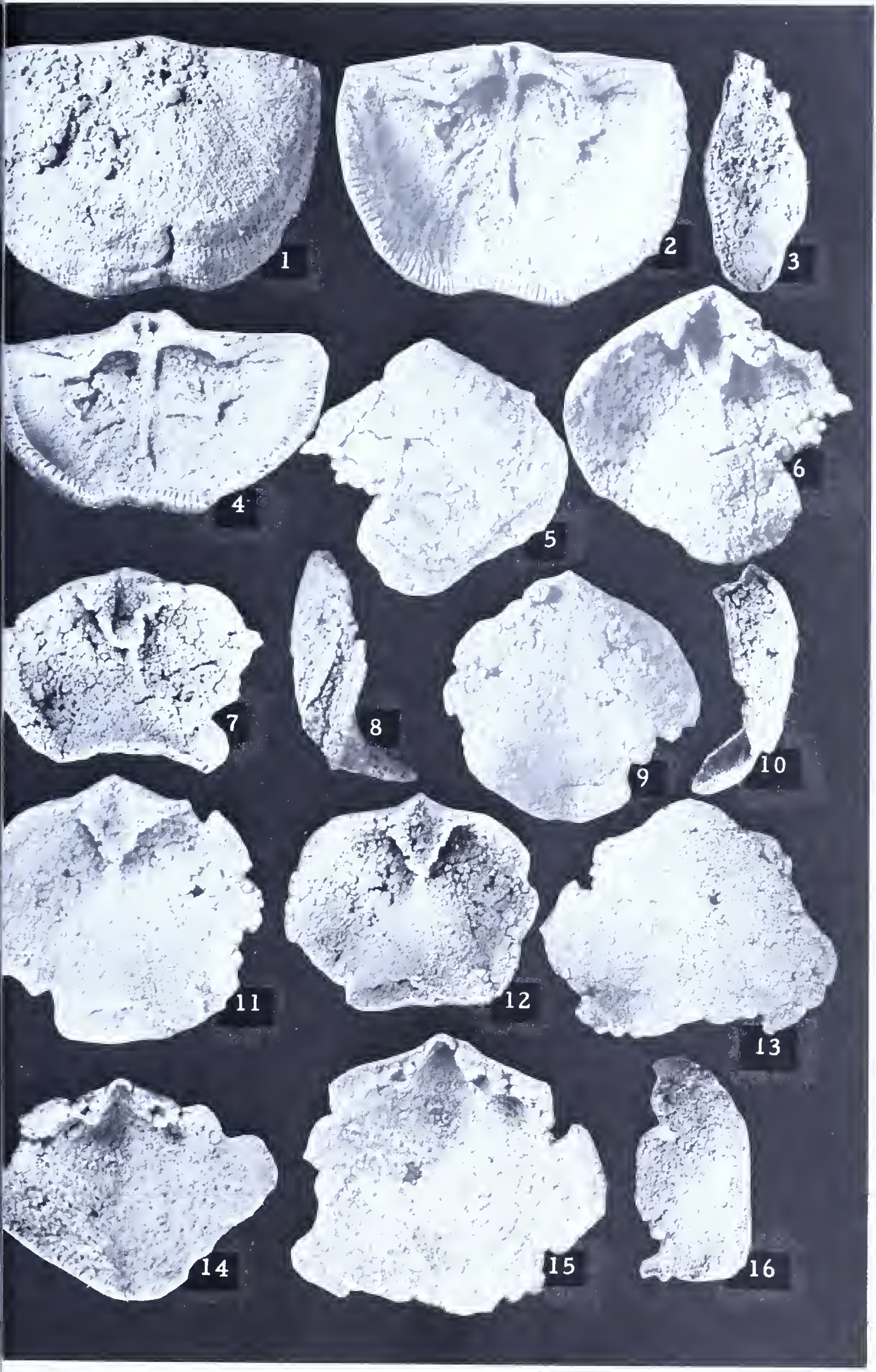
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PLATE 17.—BRACHIOPODS AND GASTROPODS FROM THE NITTANY DOLOMITE

Figures 1-19. *Syntrophinella* cf. *S. cooperi,* Williamsburg section, about 160 feet above base of Nittany Dolomite. *1-4,* X3.8, specimen N-Wb-47-1. Exterior (1), interior (2), side (3) and oblique interior (4) views of silicified pedicle valve; *5-8,* X3.8, specimen N-Wb-47-2. Exterior (5), side (6), interior (7) and oblique interior (8) views of silicified pedicle valve; *9-12,* X3.5, specimen N-Wb-47-7. Exterior (9) interior (10), oblique interior (11) and side (12) views of silicified brachial valve; *13-16,* X3.5, specimen N-Wb-47-6. Exterior (13), side (14), oblique interior (15) and interior (16) views of brachial valve; *17-19,* X3.2, specimen N-Wb-47-11. Anterior (17), posterior (18) and side (19) views of complete silicified specimen.

Figures 20 and 21. *Ophileta* cf. *O. solida,* Mount Etna section, about 1,095 feet above base of Nittany Dolomite. *20,* X1.9, specimen N-ME-188-1. Cross-sectional view of dolomitized specimen, *21,* X1.9, specimen N-ME-188-2. Cross-sectional view of dolomitized specimen.

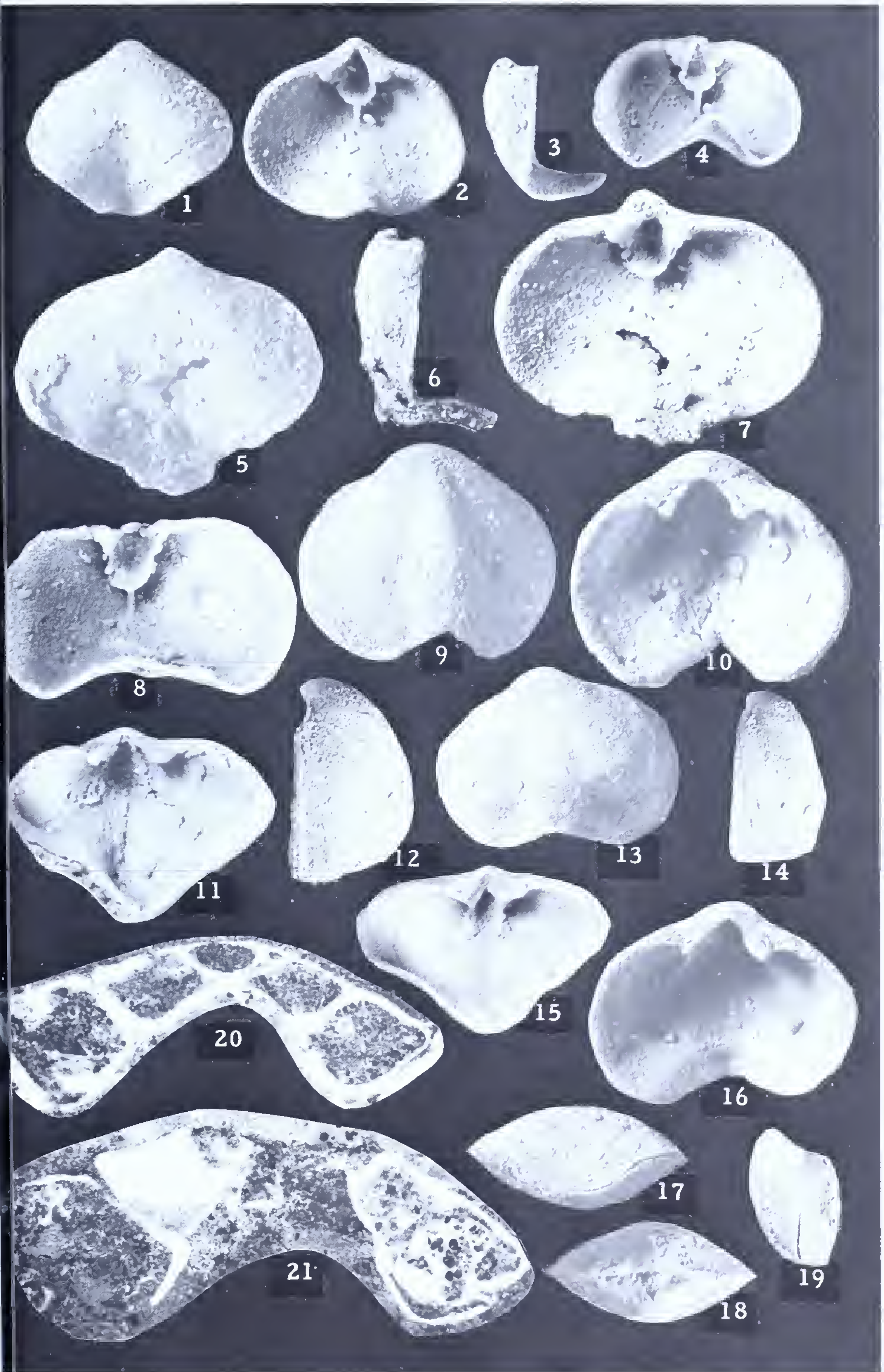
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PLATE 18.—GASTROPODS AND CRYPTOZOON CHERT FROM THE NITTANY DOLOMITE

Figures 1-4. *Lecanospira compacta,* X2.0, Williamsburg section, about 300 feet above base of Nittany Dolomite. *1-2,* specimen N-Wb-91-1a. Overhead (1) and oblique (2) view of external impression of the hyperstrophic spire in chert; *3-4,* specimen N-Wb-91-1b. Overhead (3) and oblique (4) view of the upper surface of a steinkern in chert.

Figure 5. *Lecanospira* sp., X3.5, Williamsburg section, about 160 feet above base of Nittany Dolomite. Basal view (5) of silicified shell.

Figure 6. *Lecanospira compacta,* X0.9, specimen N-Wb-91-2, Williamsburg section, about 300 feet above base of Nittany Dolomite. Cross-sectional view (6) of specimen in chert.

Figure 7. Three external impressions of *Lecanospira* in dolomite, X0.9, excavation for addition to Mineral Sciences Building on the campus of the Pennsylvania State University. First specimen from the right margin *Lecanospira* cf. *L. compacta;* other two specimens *Lecanospira* sp.

Figures 8 and 9. *Lecanospira* cf. *L. salteri,* X1.9, Bellefonte section, about 515 feet above base of Nittany Dolomite. *8,* specimen N-Bf-56-5. Cross-sectional view (8) of dolomitized specimen; *9,* specimen N-Bf-56-1. Cross-sectional view (9) of dolomitized specimen; base of specimen is missing.

Figure 10. *Lecanospira* sp., X0.9, excavation for addition to Mineral Sciences Building on the campus of the Pennsylvania State University. Cross-sectional view (10) of dolomitized specimen.

Figure 11. *Cryptozoon steeli,* scale in figure is 6 inches long, Lutzville section, from base to about 175 feet above base of Nittany Dolomite. Hemispherical specimen replaced by chert displaying poorly preserved concentric laminations.

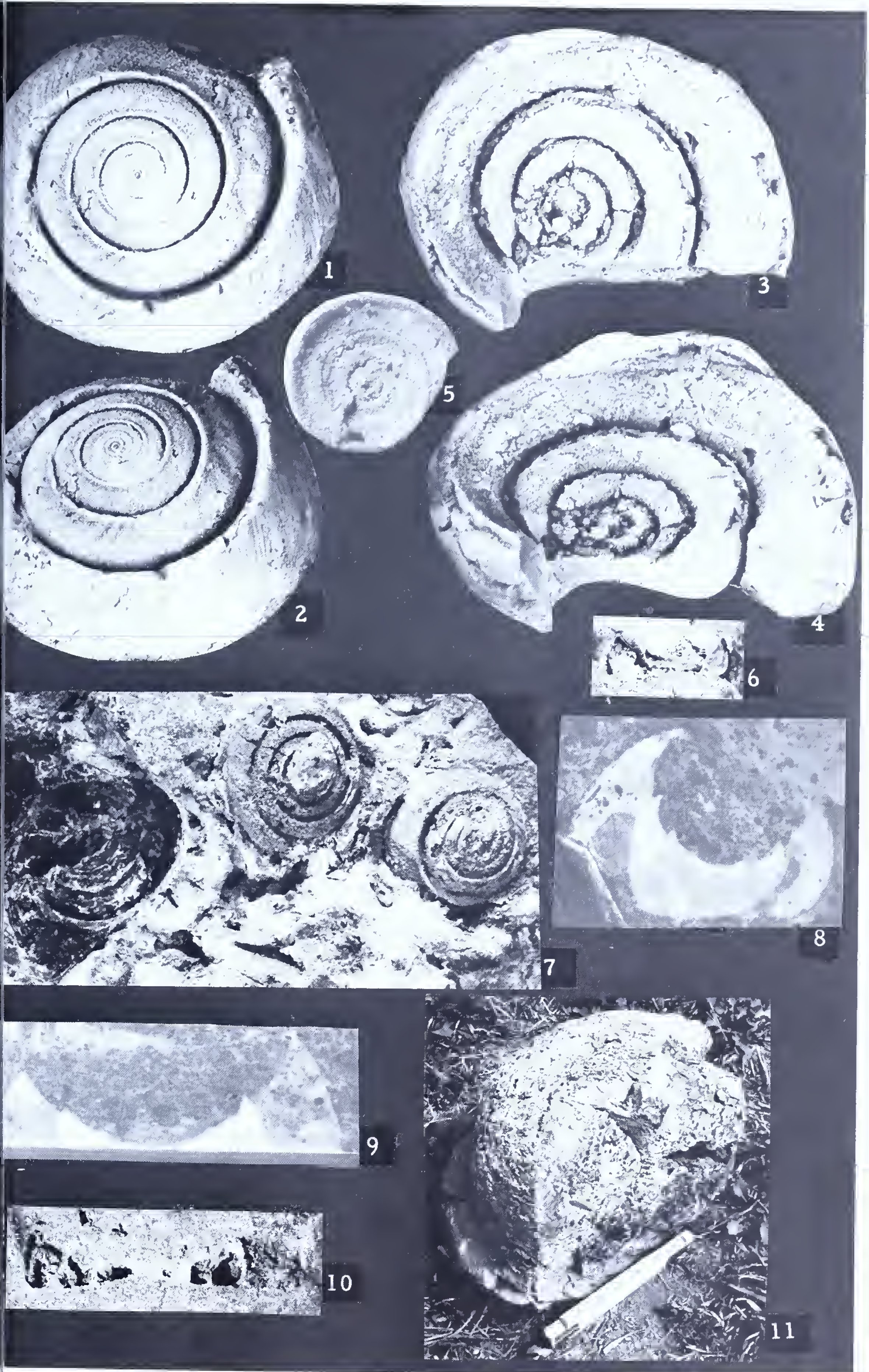
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PLATE 19.—SPONGE SPICULES, GASTROPODS AND CEPHALOPOD SIPHUNCLES FROM THE NITTANY DOLOMITE

Figure 1. Silicified oxeakloster sponge spicules; the pointed ends of most specimens are broken off, X12.0, Shoenberger section, about 190 feet below top of Nittany Dolomite.

Figures 2 and 3. *Lytospira,* sp., X2.0, Bellefonte section, about 530 feet above base of Nittany Dolomite. Cross-sectional view of coil (2) and whorl profile (3) of dolomitized specimen.

Figure 4. *Orospira,* sp., X3.2, Shoenberger section, about 130 feet below top of Nittany Dolomite. Apical view (4) of an incomplete, poorly preserved silicified specimen.

Figures 5-8. cf. *Proterocameroceras* sp., Lutzville section, 450-500 feet above base of Nittany Dolomite. *5-6,* X3.0, adoral (5), and apical (6) view of silicified specimen; *7-8,* X1.9, lateral view, venter on right (7) and dorsal view (8) of same specimen shown in Figures 5 and 6.

Figures 9-11. cf. *Clitendoceras* sp., Waterside section, about 580 feet above base of Nittany Dolomite. Ventral view, X1.9 (9), lateral view, venter on left, X1.7 (10) and adoral view, X3.0 (11) of silicified specimen.

Figures 12-15. cf. *Platysiphon* sp., Lutzville section, 450 to 500 feet above base of Nittany Dolomite. Dorsal view, X1.9 (12), ventral view, X1.9 (13), lateral view, venter on right, X1.9 (14) and adoral view, venter on bottom, X3.2 (15) of silicified specimen.


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PLATE 20.—FOSSILS FROM THE *BELLEFONTIA* ZONE OF THE STONEHENGE LIMESTONE AND LARKE DOLOMITE

Figures 1-4. *Ribeiria* cf. *R. parva,* Spruce Creek section, 0 to 45 feet below top of Stonehenge Limestone. Lateral view, X3.8 (1), and oblique interior view of broken valve showing transverse internal plate, X3.8 (2), fragment of part of shell with transverse internal plate, commonly the only portion of the shell preserved in the insoluble residue of a dolomite sample, X3.8 (3), and posterior view showing "U"-shaped keel, X3.3 (4) of silicified specimens.

Figures 5-9. *Lytospira*? *multiseptarius,* Baileyville section, 0 to 20 feet below top of Stonehenge Limestone. *5,* X3.2, view showing open coiling of silicified specimen; *6-7,* view showing open coiling, X3.4 (6) and whorl profile, X2.6 (7) of silicified specimen; *8-9,* view showing open coiling, X3.4 (8) and whorl profile, X2.6 (9) of silicified specimen.

Figures 10-25. Amphineuroid plates. *10-12,* Type I, X3.7, Spruce Creek section, 0 to 45 feet below top of Stonehenge Limestone. End view (10), upper surface (11) and lower surface (12) of silicified specimen; *13-15,* Type II, X3.3, Spruce Creek section, 0 to 45 feet below top of Stonehenge Limestone. End view, notched end up (13), upper surface (14) and lower surface (15) of silicified specimen; *16-18,* Type III, X3.3, Baileyville section, about 50 feet below base of Stonehenge Limestone. Lower surface (16), upper surface (17) and end view, notched end up (18) of silicified specimen; *19-25,* Type IV, X2.9, Lutzville section, about 100 feet below top of Larke Dolomite; *19-20,* upper surface of silicified specimens; *21-22,* upper surface (21) and end view, notched end up (22), of silicified specimen L-L-0-1; *23,* lower surface of silicified specimen L-L-0-2; *24-25,* lower surface (24) and end view, pointed end up (25), of silicified specimen L-L-0-3.


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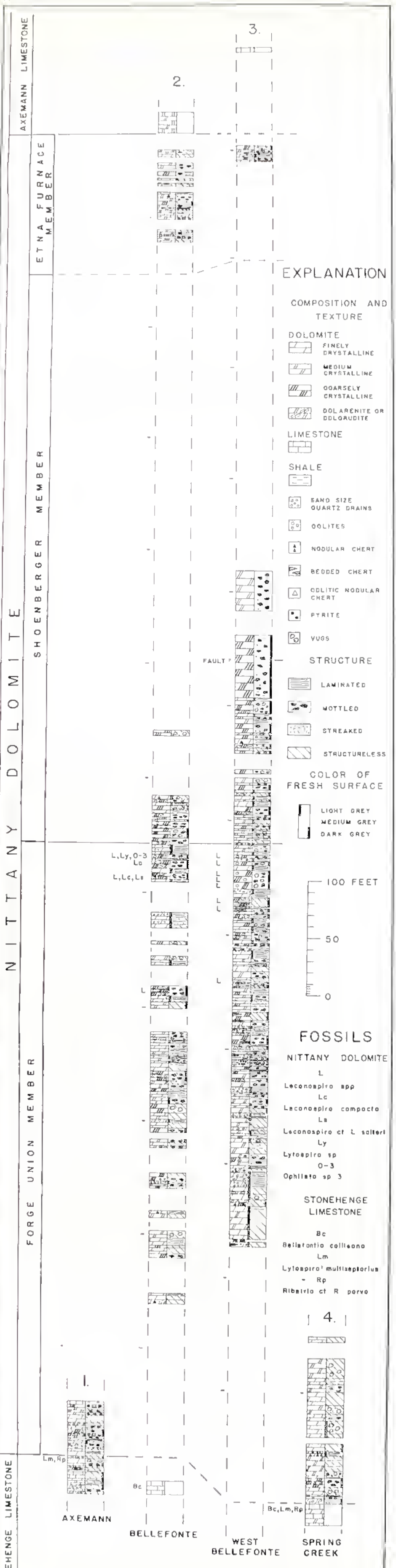

Plate 21. Detailed stratigraphic columns of the Nittany Dolomite for geologic sections measured at and in the vicinity of Bellefonte, Pennsylvania

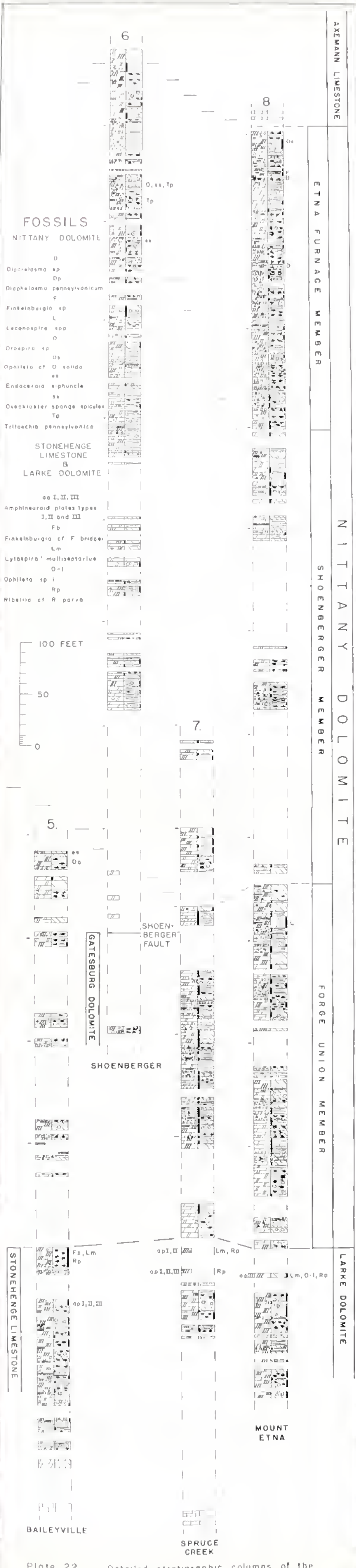

Plate 22 Detailed stratigraphic columns of the Nittany Dolomite for geologic sections measured near Baileyville, Shoenberger, Spruce Creek, and Mount Etna, Pennsylvania

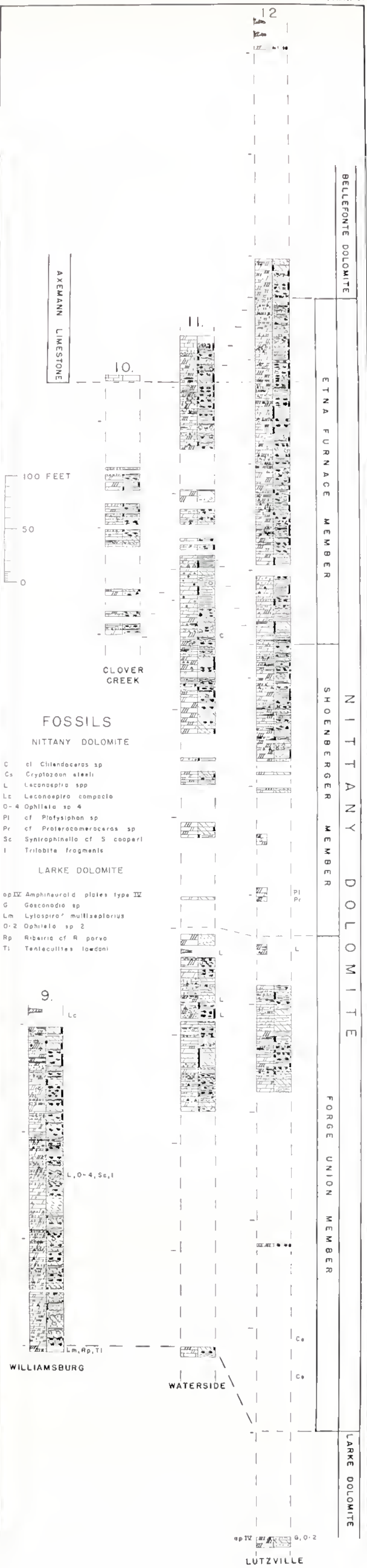

Plate 23 Detailed stratigraphic columns of the Nittany Dolomite for geologic sections measured near Williamsburg, Clover Creek, Waterside, and Lutzville, Pennsylvania

PLATE 24. GENERALIZED STRATIGRAPHIC CROSS SECTION OF THE NITTANY DOLOMITE IN CENTRAL PENNSYLVANIA